U A S Monograph Series No. 2

294

STUDIES ON THE ROOT GRUBS IN KARNATAKA

G. K. VEERESH

1977

UNIVERSITY OF AGRICULTURAL SCIENCES
HEBBAL, BANGALORE - 560 024

A. R. V. KUMAR

STUDIES ON THE ROOT GRUBS IN KARNATAKA

with special reference to bionomics and control of *Holotrichia serrata* Fabricius (Coleoptera, Melolonthinae).

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Veeresh, G.K., 1977

FOREWORD

In recent years, there has been greater emphasis on the study of basic aspects that help understanding of the various facets of a pest problem and in particular their bionomics which serves as a base for working out control measures. The Department of Entomology of the University is engaged in carrying out systematic studies on various pests prevalent in the State and the study on Root Grubs is one such.

Root grubs are manacing insect pests causing damage to a variety of crops such as cereals, millets, oil seeds, vegetables, ornamental and fruit crops and plantation crops like coconut, areca, coffee ane cardamom in India. A number of workers have paid attention to the study and control of this pest which is reported to bo causing considerable damage to a variety of crops in different parts of the country. The investigation reported in this bulletin represents a systematic study on the root grub control with special reference to bionomics and control of *Holotrichia serrata* Fabricius. The author has not only studied the existing genera and species but also recorded new species which are major pests in the different agro-climatic regions of the State. Besides effective methods of chemical control, he has suggested a number of simple mechanical and agronomic practices for the control of the pest.

It is appropriate that this important study is being published as No. 2 in the recently started Monograph Series with the main objective of making available the results of sustained work done in the University on various subjects. I hope it will be useful to scientific workers elsewhere in the country and outside.

H. R. ARAKERI
Vice-Chancellor

Author's Acknowledgement

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For identification of adults and for the supply of reprints, I am greatly indebted to the authorities of Commonwealth Institute of Entomology, British Museum, London; to Dr. G. Frey, Museum G. Frey, Tutzing, Munchen, Germany; to Dr. Paul O. Ritcher, Professor of Entomology, Oregon State University, Corvallis, U. S. A. and the Authorities of Rothamsted Experimental Station Library, Harpenden, U. K.

I am indebted to the following, for having extended their full co-operation in providing facilities to conduct experiments in their fields. Justice G. K. Govinda Bhat, Chief Justice of Karnataka and members of his family; Messers Krishnamurthy Bhat, Proprietor and Mr. A. N. Navada, the Manager, Koodanahalli Coffee Estate, Hassan District; Mr. C. K. Vijayakumar, Chitloor Acres, Hoskote, Bangalore District; Mr. Jagadish, Nandi Cross, Chikkaballapur, Kolar District; Mr. S. Siddaveerappa and brothers, Thondavadi, Mysore District; Mr. Bagali Mohidin Saheb, Chitwadigi Hospet, Bellary District and the authorities of Ugar Sugar Works Ugar–khurd, Belgaum District.

Dr. Rodger Mitchel, Visiting Professor from Columbus, Ohio State University U.S.A. has kindly gone through the manuscript and given suggestions for which I express my gratitude.

This manual would not have come out, but for the initiative taken by the University of Agricultural Sciences to publish it in the Research Series. I am grateful to the University of Agricultural Sciences for

bringing out this series. I acknowledge the help of Artist, L. Seetaram of Icon-Studio, Bangalore.

The information published in this Research Series, is the author's own work carried out during the last eight years at the University of Agricultural Sciences, Bangalore. Part of this work was submitted for the author's Doctoral thesis. I gratefully acknowledge all the facilities provided by the University of Agricultural Sciences during the course of this work.

My indebtedness to all my colleagues in the Department of Entomology, University of Agricultural Sciences, who have extended their help in connection with these studies.

G. K. VEERESH

July, 1977

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INTRODUCTION

The scarabaeid subfamily Melolonthinae (Coleoptera) is world wide in distribution, and many of the most injurious species of the family Scarabaeidae, belong to this group. Adults of most genera in the subfamily feed extensively on the foliage of trees and shrubs and are commonly known as chafers, May beetles or June beetles. The larvae of these beetles are known universally as white grubs or root grubs, since they are subterranean feeders on the roots and underground stem of living plants.

The larvae of some melolonthine beetles are major pests in several parts of the world. One of the most famous members of the group is the European "hanneton" *Melolontha melolontha* Linnaeus, which has been known for over a century as a destructive enemy of the roots of crops. Certain species of *Phyllophaga*, both adults and larvae, are perhaps the most destructive members of the family and they have been known for over two centuries in the Western hemisphere (Hayes, 1925), White grubs have long been considered the most important pests of sugarcane in Australia (Mungomery, 1948), Mauritius (Mautia, 1935), Puerto Rico (Wolcott, 1935) and Tanganyika (Jepson, 1956).

In India there have been reports of the wide spread damage due to melolonthine grubs in recent years (Prasad and Thakur, 1959; Prasad, 1961; Desai and Patel, 1965; Avasthy, 1967; Patel and Vyas, 1967; Rai *et al.*, 1969; Sharma, 1974; D'Souza and Krishnamoorthy Bhat, 1974; Raodeo, 1974; Sachan and Pal, 1974; Chandy Kurian and Abdulla Koya, 1974; Purani *et al.*, 1975). White grub is one of the five national pests and a large sum of money is set apart to control this pest at National level (Banerjee, 1976).

In Karnataka the larvae of the subfamily melolonthinae are among the most serious pests and they occur in almost every district. The crops damaged by these pests include cereals, millets, oil seeds, vegetables, ornamental and fruit plants and plantation crops like areca, coconut, coffee and cardamom. At several places fertile cultivable lands are left fallow due to the ravages of these pests during the main cropping season between June and September (Veeresh, 1973).

The adult beetles attack several ornamental and orchard crops and are becoming major pests in vineyard which are being extended every year around Bangalore.

The present investigation is aimed at :

1) Obtaining information on the important species of melolonthine beetles that occur in Karnataka, their seasonal history, and the crops that are subjected to the attack of the grubs ;

2) To study the bionomics of the most commonly occurring species, *viz.*, *Holotrichia serrata* Fabricius so that the weak link in its life cycle is determined for easy control measures ; and

3) To find out suitable effective control measures for root grubs and chafers in the State. For this purpose an integrated approach was envisaged in the management of the pest.

Morphological studies of the adult and larva of *H. serrata* were under taken as a basis for formulation of keys and the classification of the melolonthinae occurring in the State.

It is hoped that this study will supply basic information on the melolonthine beetles of economic importance in the State and also will help in recommending timely suitable control measures against the root grub attack in general.

2. Faunistic study of melolonthine beetles of Karnataka

The faunistic study revealed fourteen species of melolonthine beetles collected from different parts of Karnataka (Fig. 1). These are placed under five genera of the sub-family Melolonthinae (Coleoptera). A brief description of adults, their occurrence, host range, nature of damage is included under each species. Keys for distinguishing the genera and species reported here are included.

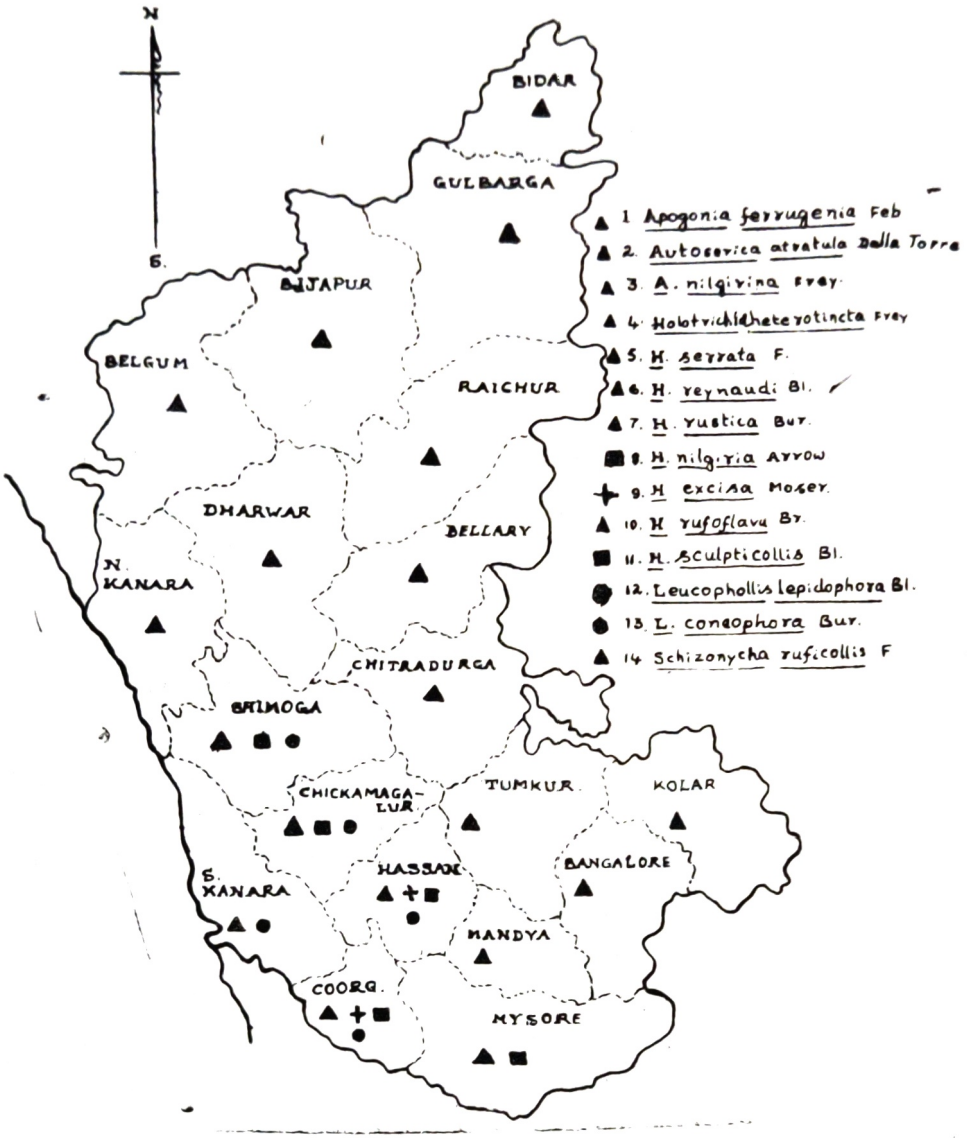


Fig 1. Map showing the distribution of different species of white grubs (Melolonthine beetles) in Karnataka.

A conspectus of the species reported here is given below :

1. *Apogonia ferugenia* Fabricius
2. *Autoserica atratula* Dalla Torre
3. *Autoserica nilgirina* Frey
4. *Holotrichia excisa* Moser
5. *Holotrichia heterotincta* Frey
6. *Holotrichia nilgiria* Arrow
7. *Holotrichia reynaudi* Blanchard
8. *Holotrichia rustica* Burmeister

9. *Holotrichia rufoflava* Brenske
10. *Holotrichia serrata* Fabricius
11. *Holotrichia sculpticollis* Blanchard
12. *Leucopholis coneophora* Burmeister
13. *Leucopholis lepidophora* Blanchard
14. *Schizonycha ruficollis* (Fabricius)

A list of localities and the important crops of that locality where adults and grubs collected for the study is given below :

Districts	*Localities*	*Important crops*
1. Mysore	Nanjangud, Gundlupet, Chamarajanagar, K.R. Nagar, Kollegal, B.R. Hills, Mysore.	sugarcane, sorghum and coffee.
2. Mandya	Nagamangala, Pandavapura.	banana, sorghum and ragi.
3. Bangalore	Hoskote, Doddaballapur, Devanahally, Yelahanka, Kengery, Kanakapura, Hebbal, Bangalore city, Doddkuppe village.	vegetables, mulberry, cucurbits, grapes, chilleis, maize, ragi and citronella grass.
4. Kolar	Melur, Sidlagatta, Chickballapur, Srinivaspura.	vegetables, mulberry, cucurbits, grapes, chillies, maize and sorghum.
5. Tumkur	Madhugiri, Sira	coconut, maize, ragi and sorghum.
6. Hassan	Koodanahalli Estate, Doddalakkunda Estate, Dyndigatta Estate, Dythapura Estate.	coffee
7. Coorg	Balakadu Estate Suntikoppa Estate, Vishalakshi Estate, Siddapur, Hosabeed Estate	coffee
8. South Kanara	Vittal, Subramanya	areca

9. Chickmagalore	Sringeri, Balehonnur, Guddadamane Estate, Aldur.	coffee and areca
10. Shimoga	Hirethota, Thirthahally, Devangi Mudaba Estate.	areca
11. Chitradurga	Hiriyur	sorghum
12. Bellary	Hospet, Hampi, Kamalapur.	sugarcane
13. Dharwar	Dharwar, Kundagol	chillies, cotton and groundnut.
14. North Kanara	Sirsi, Siddapur, Kumta, Ankola	areca, cardamom
15. Belgaum	Ramdurg, Nippani Khanapur, Gokak, Arabhavi, Bailhongal, Hukkeri, Ugarkhurd.	sorghum, tobacco, maize, chillies and sugarcane
16. Bijapur	Mudda, Jamakandi	sorghum
17. Raichur	Sindhanur, Gangavathi	sugarcane
18. Gulbarga	Chincholi	sorghum
19. Bidar	Bidar	sorghum

2.1 Key to the known Genera of Melolonthini of Karnataka

The genera of adult melolonthine beetles encountered during the present study can be distinguished with the following key :

1. Labrum connate ; hind tibia flattened ; last segment of the maxillary palp not flattened dorsally.....Gen. *Autoserica* Brenska

— Labrum free, hind tibia not flattened, last segment of the maxillary palp may or may not be flattened with a depression dorsally..... 2

2. Body and elytra with distinct scales, last segment of the maxillary palp with a flattened dorsal depression.....Gen. *Leucopholis* Brenske

— Body and elytra without distinct scales, last segment of the maxillary palp with or without a dorsal depression..... 3

3. Clypeus extending laterally on either side dividing the compound eye into two ..... Gen. *Apogonia* Kirby

— Clypeus not extending laterally 4

4. Claws bifid towards the tip, the outer being smaller than the inner ..... Gen. *Schizonicha* Blanchard

— Claws bifid towards the middle, the outer being bigger than the inner ..... Gen. *Holotrichia* Hope.

2.2 Key to the known species of *Holotrichia*

The Eight species of *Holotrichia* encountered in Karnataka can be distinguishable by the following key :

1. Head and pronotum dark ; paramera Fig. 6 ..... *heterotincta* Frey

— Head and pronotum not dark 2

2. Elytra without hairs(naked), compound eyes dark. 5

— Elytra with hairs (tomentose) ; compound eyes shining 3

3. Antennal club long, longer than the stem of the antennae (ring segment), forehead rough, rugose, bright brown length 13 mm; paramera Fig. 7 ..... *nilgiria* Arrow

— Antennal club short, shorter than the stem of antenna (ring segment)..... 4

4. Second antennal segment shorter than segment 3 to 7 ; clypeus deep and broadly rounded ; elytra brown to dark brown ; length 20 mm ; Paramera Fig. 5 ..... *excisa* Moser

— Second antennal segment nearly as long as joints 3–7, pronotal lateral margin is acute posteriorly, elytra tomentose ; length 20-22mm ; paramera Fig. 10..... *rufoflava* Brenske

5. Pronotal margin deeply serrated, clypeus edge much bent up : tibial spine acute ; length 22–25 mm ; paramera Fig. 11 ..... *serrata* Fabricius

— Not as above..... 6

6. Labrum deeply cut in the centre, depressed. Legs slender and narrow, foreleg pretarsus long beetles somewhat flattened. Length 14–15 mm; Paramera Fig. 12.....*sculpticollis* Blanchard

— Labrum even, Legs normal, Thorax covered with thick long white hairs ventrally in between 1st and 3rd pair of legs..... 7

7. Antennal club equal to or shorter than 2nd joint. Length 19 mm; Paramera, Fig. 8.....*reynaudi* Blanchard

— Antennal club longer than the 2nd Antennal joint. Length 16–18 mm; Paramera Fig. 9..... *rustica* Burmeister

2.3 Adult descriptions and distribution

Apogonia ferruginea Fabricius (Fig. 2)

Fabricius 1781, Spec. Ins. 1 : 41.

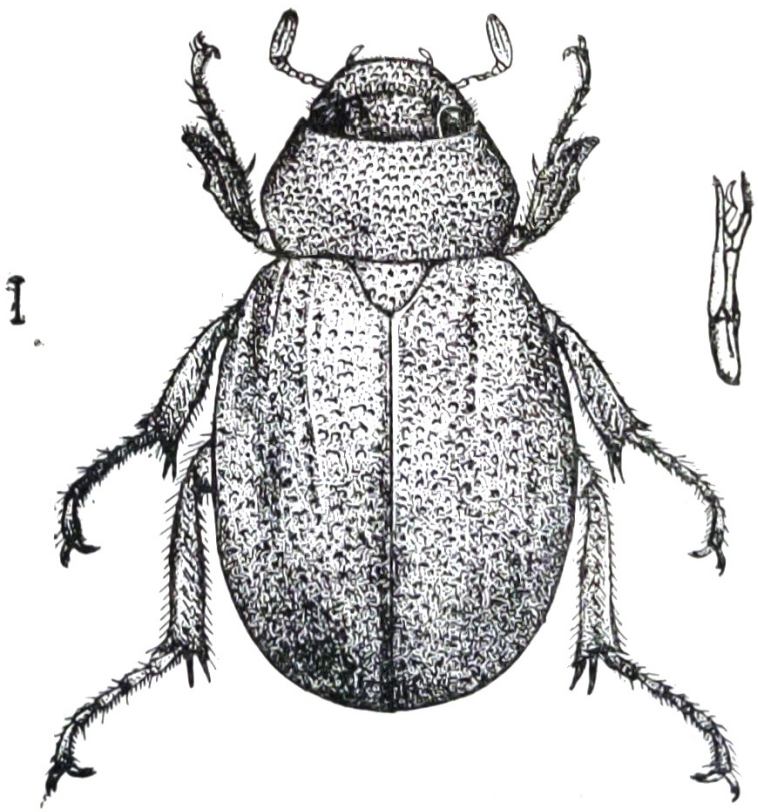


Fig 2. *Apogonia ferruginea* Fabricius, (Left; actual length; Right: Paramera, similar to all adult beetle diagrams)

The adult dark brown, shining with close and deep punctations; Underside of the abdomen pubescent; clypeus emarginate, extending across the compound eyes; Head broader than long, oval. Elytra elevated along the suture. Length 7–8 mm. Paramera Fig. 2.

It was distributed througout the State. The adult has been reported to defoliate *Salmalia malbarica* by Mathur and Balvant Singh (1960). It was one of the smallest melolonthine beetles collected at light. Large number of adults were attracted at light immediately after the rains in summer, and found active during April–September.

Fletcher (1919) and Roonwal (1954) have reported the grubs of *Apogonia* feeding on sugarcane roots. Adults are known to attack grape vine leaves (Batra *et al.*, 1973).

Autoserica atratula Dalla Torre (Fig. 3).

Dalla Torre 1912, Col. Cat. 46 (45): 20.

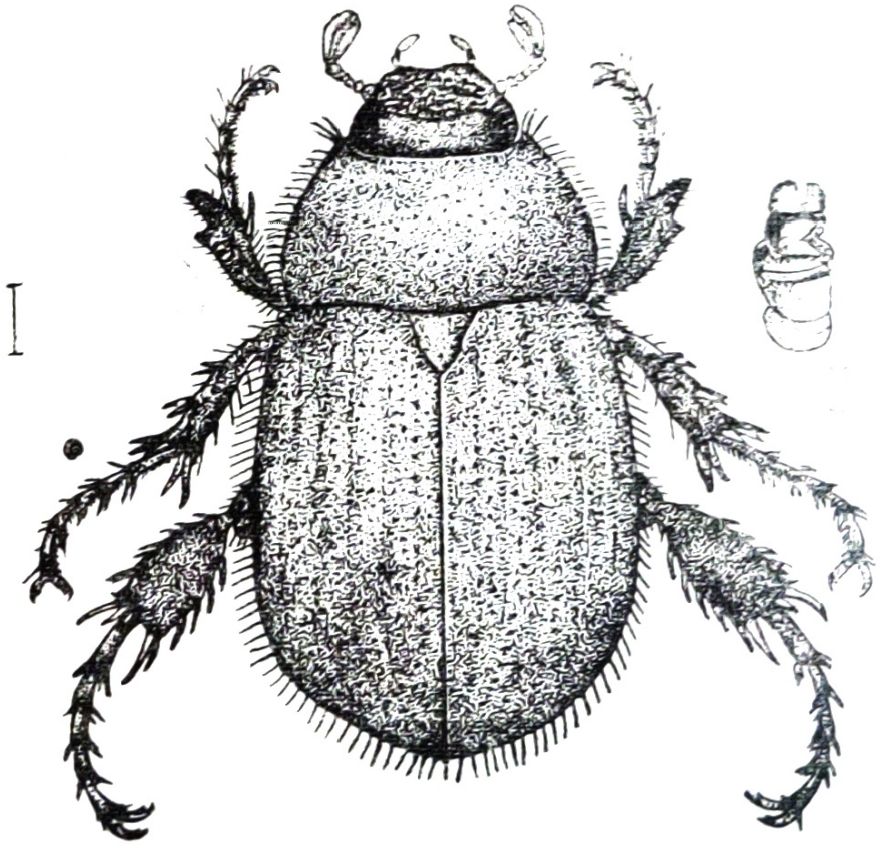


Fig. 3 *Autoserica atratula* Dalla Torre

The adult oval shining velvety, crimson dark, cherry coloured beetle; Labrum connate, clypeus roughly rugose, upper surface of head

smooth, antennae 11-segmented, 3rd segment bead like, segments 4 to 8 somewhat serrated; elytra with longitudinal parallel striations and with irregular punctations. Hind tibia is broad. Length 11-12 mm, Paramera Fig. 3.

The species distributed throughout the State and adults were active from April to December. They were feeding on redgram leaf (*Cajanus cajan*) during day time in August 1972 at Lokkanahalli, Kollegal, Mysore district. Large number of these were attracted to light. Adults feed on rose flowers and leaves.

Autoserica nilgirina Frey (Fig. 4)
Frey 1972, Ent. Arb. Mus. Frey 23 : 187

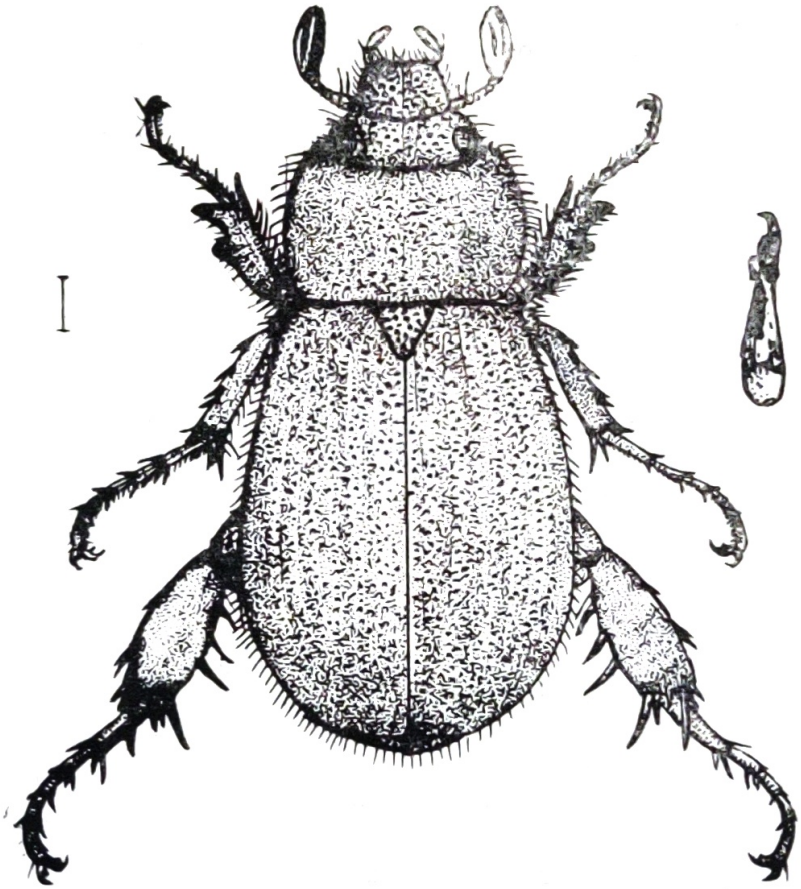


Fig 4. *Autoserica nilgirina* Frey

The adult reddish brown; pronotum crimson red; antenna 10 segmented. Length 8-9 mm. Paramera Fig. 4.

It was found distributed throughout the State. The adults were attracted to light from April to December.

Nomonclature of the genus *Holotrichia*

There is a good deal of confusion about the identity and nomenclature of the genus *Holotrichia* in this country. Two names are commonly used for this genus in India, *Lachnosterna* and *Holotrichia* (Stebbing, 1899; Fletcher, 1921; Lefroy. 1900: Beeson, 1941; Gupta and Avasthy, 1957; Hoq, 1962; Devid and Kalra, 1966). In recent years the specialists of the British Museum, London identified the genus as *Phyllophaga* (*Phyllophaga serrata*). The two genera *Holotrichia* and *Lachnosterna* were described by Hope (1837) on the successive pages of the Coleopterist's Manual (Part I, page 99 and 100).

Holotrichia was treated as Synonym of *Lachnosterna* in the Munich Catalogue of 1869, but the Dalla Torre catalogue of 1912-13 revived *Holotrichia* for Old world species and employed *Lachonostena* for those of New world. Arrow (1948) concludes that '*Lachonosterna* Hope, so long in general use both in Europe and America is certainly to be preferred and the appearance of the name *Holotrichia* on the preceeding page to *Lachnosterna* is of no real priority'.

The name *Phyllophaga* was proposed by Harris in 1826. Leconte (1855), after considering the history of these names, was convinced that for the sake of purity in nomenclature, the name *Lachnosterna* should be adopted and that *Phyllophaga* and *Ancylonycha* should be rejected since they were not supported by valid description to indicate the limits of the genus. Lacordaire (1856) was in accord with this view and pointed out that the name *Phyllophaga* Harris was a *nomen-nudum* and should therefore be rejected.

The name '*Phyllophaga* was revived by Glasogow (1916) on the ground that its validity was fully established by its publication in connection with a series of valid specific names'. His argument for the change was supported by the International Code (Hayes, 1925).

Saylor (1937) and Arrow (1948) regarded both old and new world species as congeneric. If they are followed, the valid name of the genus is *Phyllophaga* Harris as this name is available according to the International Code of Zoological nomenclature. Fennah (1972) however stated that *Lachnosterna* Hope is synonym of *Phyllophaga* and not *Holotrichia*. Frey (1971) has kept the old World species separate and retained *Holotrichia* Hope for this, and the name *Phyllophaga*

being restricted to those of the New World. In the latest book of Entomological works from Museum G. Frey, he has included 96 species under the genus *Holotrichia* under 5 groups from the Indian Sub-Continent, seven species of which are included in this bulletin.

Arrow (1948) has listed the following six genera as synonyms: *Lachnosterna* Hope 1837; *Brahmina* Blanchard 1850; *Hoplochelus* Blanchand 1851; *Anomalochela* Moser 1913, *Ancylonvcha* Blanchard 1845; and *Cnemarchis* Saylor 1942. Frey (1971) has considered the genus *Brahmina* as distinct from *Holotrichia*.

In recent years, the workers in India have used the generic names *Lachnosterna* (Prasad and Thakur, 1959; Haq, 1963; Sinde and Sharma, 1970 and 1971; Sharma *et al.*, 1971; Bindra and Singh, 1971) and *Phyllophaga* (Venkataramaiah, 1969; D'Souza *et al.*, 1960) in place of *Holotrichia* for the several commonly occurring species like *H. consanguinea; H. serrata* and *H. nilgiria*. The two genera *Lachnosterna* and *Phyllophaga* are restricted to the continental Europe and America respectively according to Arrow (1948) and Frey (1971).

To avoid further confusion, the genus *Holotrichia* is retained in the present study as this name (i) has been more commonly used for a long time in India, (ii) Satisfies the law of priority [as it appears on the preceding page to *Lachnosterna* in the Hope's (1937) description] and (iii) as also recognised by Frey (1971).

Holotrichia excisa Moser (Fig. 5)

Moser 1913, Deutsche Ent. Zeits. p. 53.

In General shape resembles *H. reynaudi*, but slightly narrower and elongate, reddish brown, punctation deeper, and denser on head and pronotum; elytra is elevated along the suture; labrum deeply divided. Length 18–20 mm; Paramera Fig. 5.

It was collected from Balekadu, Suntikoppa, Vishalakshi, Siddapur estates in Coorg district. Larva damaged the roots of coffee. Frey (1971) and Kashi Viswanathan and Shamanna (1972) have reported this species from South India.

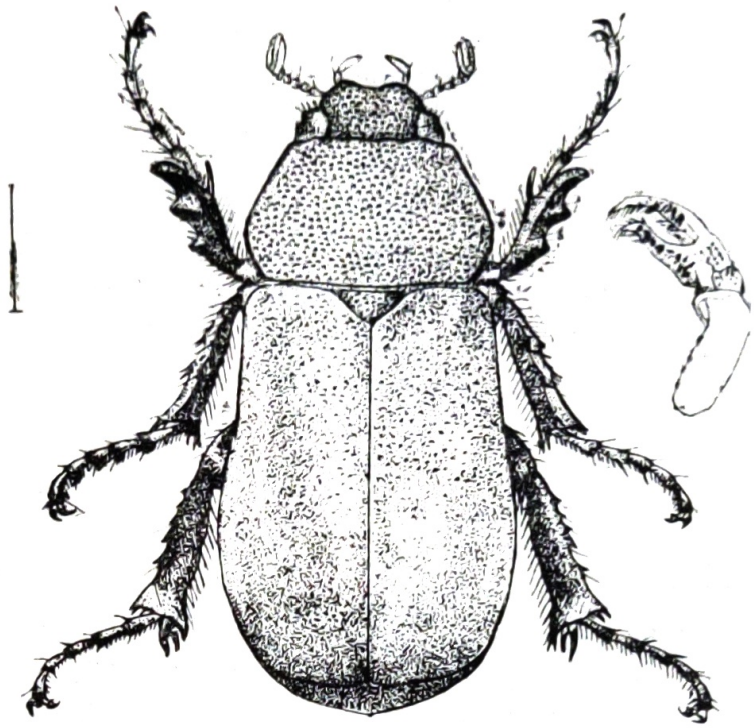


Fig 5. *Holotrichia excisa* Moser

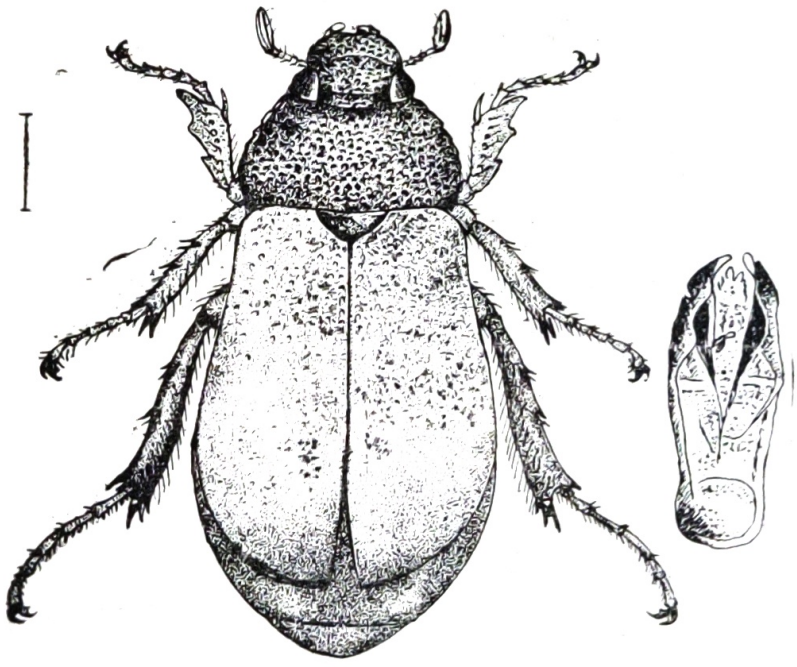


Fig 6. *Holotrichia heterotincta* Frey

Holotrichia heterotincta Frey (Fig. 6)

Frey 1976, Ent. Arb. Mus. Frey (in print).

Head and pronotum dark brown to chocolate in color, punctations uniform, clypeus entire; slightly raised anteriorly, pronotal margin with slight serration, antennal club longer than the stem in male ; elytra and body reddish brown, somewhat shining. Length 12–14 mm ; Paramera Fig. 6.

It was mostly associated with *H. serrata* in its distribution in Karnataka, but present in very small numbers.

Holotrichia nilgiria Arrow (Fig. 7)

Arrow 1944, Ann. Mag. N.H. (11) 11 : 636.

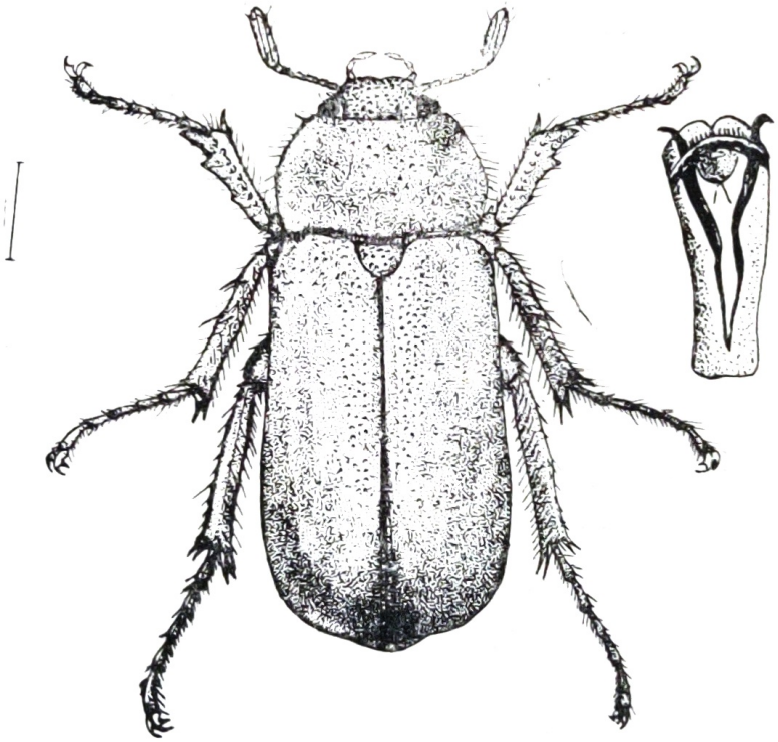


Fig 7. *Holotrichia nilgiria* Arrow

A medium sized beetle with body elongate, moderately shining, rufocastaneous, copper reddish, eyes black, punctation sparse and irregular ; antennae 10 segmented, the club about as long as joints 2–7 ; elytra elevated along the suture and each with 3 other longitudinal elevations. Length 14–15 mm. Paramera Fig. 7.

This species was collected from Dindighatta, Dythapur, Koodenahally and Doddalakkunda estates (Hassan district), Mudaba Estate (Shimoga district), Guddadamane Estate, Aldur, Attikhan Estate

(Chickmagalore district), B. R. Hills (Mysore district). The grubs caused extensive damage to coffee plants, particularly in the new clearings and replantations in the above Estates. The adults emerged twice a year, once in September after a break in the monsoon accompanied by heavy rains and another time in April, after the first summer rains. Adults preferred to lay eggs in open area around newly planted coffee plants. In one instance 59 adults were dug open around a single two-year old plant in Koodanahally Estate. large numbers of adults were attracted to light immediately after dusk and the activity of adults stopped after 10 p.m. The peak damaging period of the grubs was found during August-October. It seems to have well adapted to laterite soils in the heavy rainfall areas where other species particularly *H. serrata* have not been able to establish as malor pest.

Anstead (1915) and Mayne (1932) were the first to report damage due to grubs to coffee plants. Kashi Viswanathan and Shamanna (1972) have made some observations on the behaviour of this species. Venkataramaiah (1969) has studied the life history. Nature of damage and control measures have been reported by D'Souza *et al.* (1970) and D'Souza and Krishnamurthy Bhat (1974).

Kashi Viswanathan and Shamanna (1972) recorded the flight activity of adult from July to November. However, the adults did not live for more than three weeks under laboratory conditions (Vijayamohan Reddy, 1976). Samples received from the Manager, Attikhan Estate, B. R. Hills, Mysore on 8–5–1973, contained the last instar grub, pupa and adults. Another sample of adult beetles collected by Vijaya Mohanreddy (1976) from Urvinkhan Estate, Chickmagalore during October 1975 laid fertile eggs in the same month and adult emerged in the month of June 1976. This species seems to have two life cycles in a year which is a rare phenomenon for melolonthine beetles.

Holotrichia reynaudi Blanchard (Fig. 8)
Syn. *H. insularis* Brenske

Brenske 1894, Mem. Soc. Ent. Belg. **2**: 67.
Blanchard 1850, Cat. Col. Ent. **1**: 139.

The beetle looks like that of *H. serrata* in form and colour except in size and difference in the paramera. The pronotal margin is not serrated. Length 18 mm; parmera, Fig. 8.

Beetles generally emerged during April after the first rains. Stray cases of adults of this species have been observed during October to December also. The adults prefer to feed on drumstick (*Moringa oleifera*). The larvae of this species were found damaging groundnut at Doddakuppe Village (Bangalore district) along with *H. serrata*

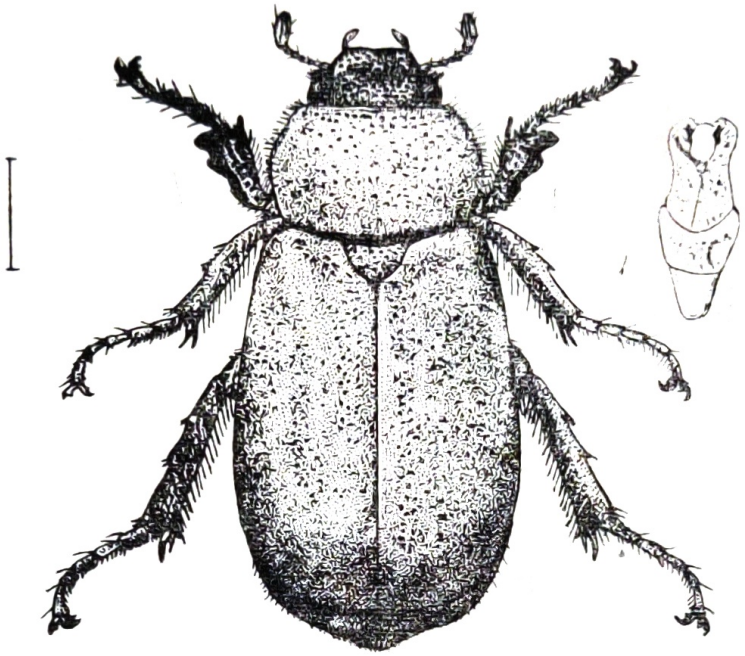


Fig 8. *Holotrichia reynaudi* Blanchard

during September 1971. Distribution throughout the State. Srivatsava and Khan (1963) have worked on the binomics and control of this species. Frey (1971) has reported this species from Ceylon.

Holotrichia rustica Burmeister (Fig. 9)

Burmeister 1855, Handb. Ent. IV. **2**: 313.

This bettle is very similar to *H. reynaudi* but smaller in size measures 16–17 mm. Paramera Fig. 9. It has also marked preference for drumstick (*Moringa oleifera*). It is encountered from all the districts of the State. Frey (1971) has reported this from South India.

Holotrichia rufoflava Brenske (Fig. 10)

Brenske 1894, Mem. Soc. Ent. Belg. 11 : 63.

It is close to *H. excisa* in its general appearance. The punctations on clypeus and head closer and deeper; second antennal segment as long as joints 3–7; pronotal lateral margin acute posteriorly: elytra tomentose, elevated along the suture with 2 other longitudinal elevations in each. Length 20–22 mm. Paramera Fig. 10.

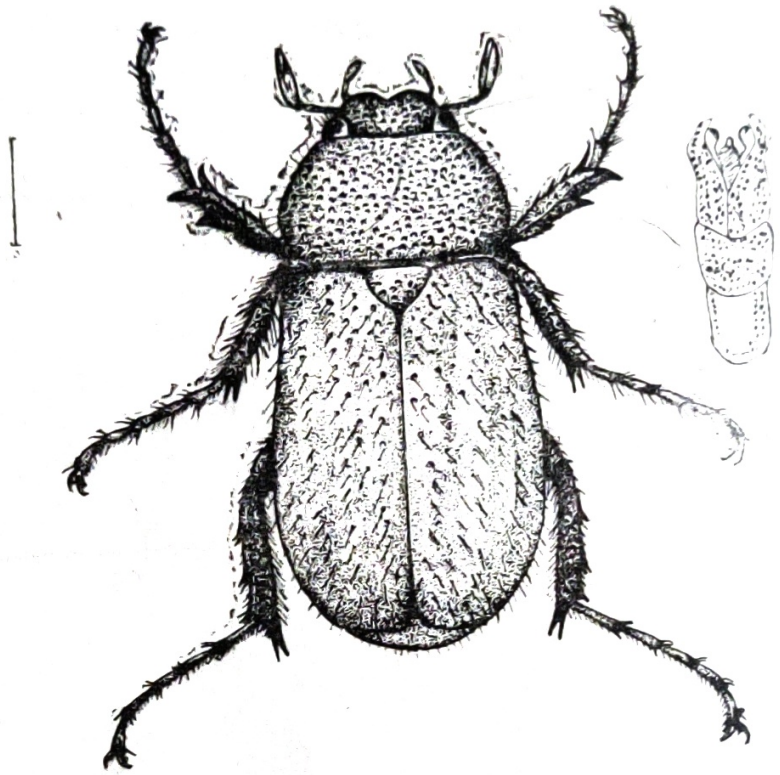


Fig 9. *Holotrichia rustica* Burmeister

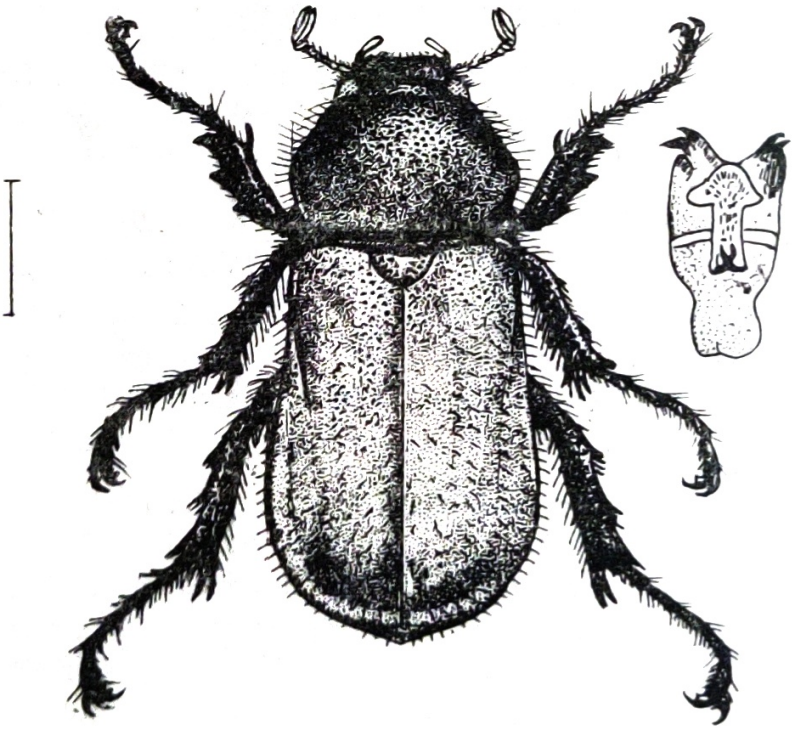


Fig 10. *Holotrichia rufoflava* Brenske

This species is widely distributed in Karnataka and collected mostly in small numbers along with *H. serrata.* It is attracted to light.

Holotrichia serrata Fabricius (Fig. 11)

Fabricius 1781, Spec. Ins. 1 : 35
Syn *H. ceylonensis* Moser,
Moser 1912, Ann. Soc. ent. Belgique 56 : 423.
H. serraticollis Mosor, Moser 1912, Ibid. 56 : 423.

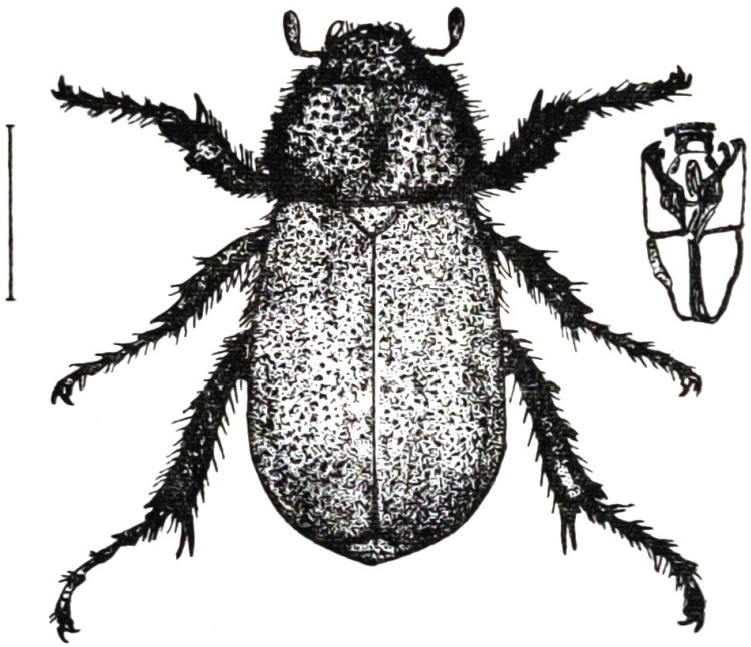


Fig 11. *Holotrichia serrata* Fabricius

The adults reddish brown often with dark tinge ; head oblique, transverse, punctation prominent: antennae 10 segmented, apical 3 segments form lamellate club, maxillary palp 4th segment oblong . pronotal margin serrated. Hind tibia with spiny ridge : Male slightly smaller than female. Length 22–25 mm. paramera Fig. 11.

Adults of this species have been collected from all the districts of the State. It was found endemic in the districts of Mysore, Bangalore, Kolar, Tumkur, Raichur, Belgaum and Bellary where the larvae caused sever damage to vegetables, pulses, oil seeds cereals, millets,

tobacco and sugarcane. Adults fed on grape vine peach, apple and guava. The adults were attracted to neem (*Azadirachta indica* Ajess *Switenia mahagoni* Linn) and *Acasia arabica*.

Earlier this was reported from Hospet, Bellary district (David and Kalra, 1964); Coimbatore (Avasthy, 1967); Calcutta (Mukerjea, 1964); Namkum, Ranchi (Majumdar and Teotia (1965) and Ceylon (Frey 1971). Majunder and Teotia 1965. have recorded this as a severe pest on palas (*Butea monosperma*) in its adult stage. According to Krishnaswamy *et. al.*; (1963) *H. serrata* completelydefoliated palas at Namkum during 1962.

The grubs of this species cause extensive damage to the cultivated crops wherever present. It is one of the majort pests on sugarcane roots (Fig. 23A) year after year in Tungabhadra Project area in Karnataka and rainfed and irrigated sorghum in Mysore district. Many fertile lands in Bangalore, Kolar and Tumkur districts have been forced out of cultivation during June–September due to the menacing problem of the white grubs of this species.

A detailed account on the bionomics and control measures of this species is presented below.

Holotrichia sculpticollis Blanchard (Fig. 12)

Blanchard 1850, Cat. Coll. Ent. 1 : 139

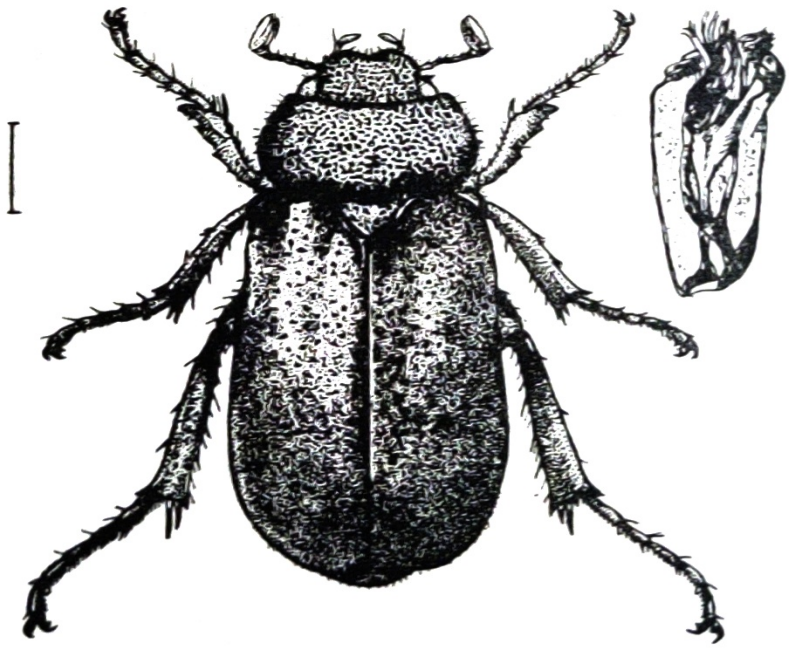


Fig 12 *Holotrichia sculpticollis* Blanchard

The adult chacolate dark, Somewhat flattened beetle ; punctations on the clypeus and head irrigular, rugose, closer on pronotum and elytra , labrum deeply cut in the centre where it is slightly depressed ; legs slender and narrow, fore leg pretarsus long. Length 14–15 mm paramera Fig. 12.

This species was found in all coffee growing areas of the State damaging coffee roots. It was associated with *H. nilgiria* in small numbers but occasionally found predominating in some estates.

Leucopholis coneophora Burmeister (Fig. 13)

Burmeister 1855, Handb. Ent. IV, 2 ; 303.

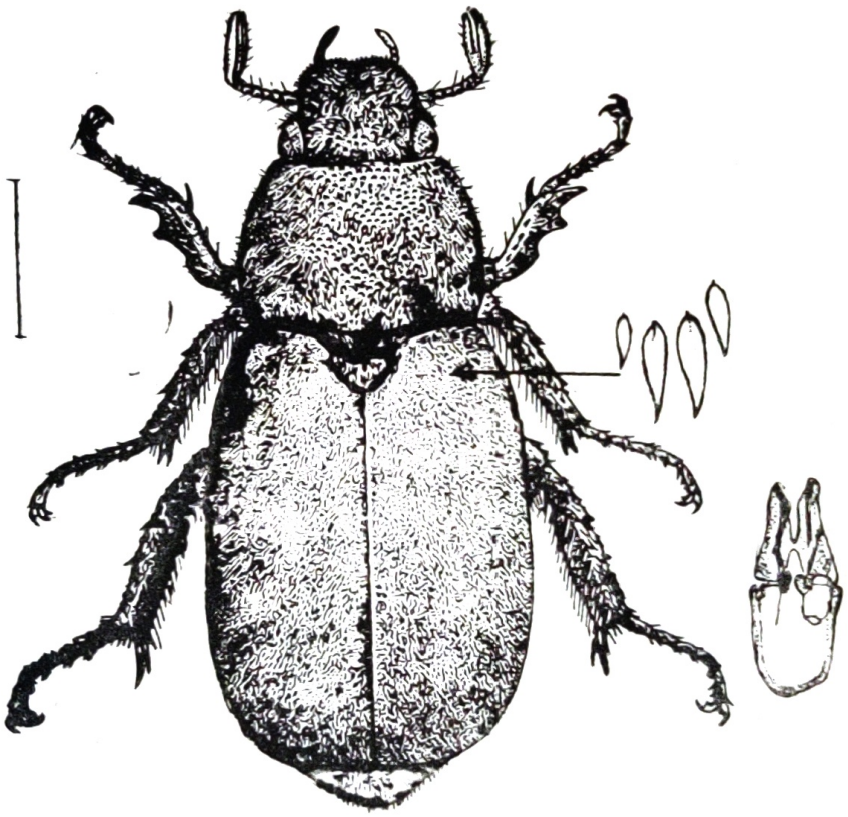


Fig 13. *Leucopholis coneophora* Burmeitser with scales magnified

Adult reddish brown chestnut coloured, somewhat flattened narrowed anteriorly ; body, appendages and clytra eovered with oval pointed yellowish brown scales and scattered amongst these are the bigger and elongate oval white scales (Fig. 13) ; antennal club longer than 3rd to 7th segment ; pygidium triangulate and pointed. Length 23–24 mm. Paramera Fig. 13.

This species was confined to heavy rainfall area of North and South Kanara, Shimoga and Chickmagalore districts. The larval stage was collected in areca gardens in Sirsi, Siddapura (North Kanara); Hirethota, Devangi (Shimoga); Sringeri (Chickmagalore) and Vittal (South Kanara). The larva fed on the roots of areca palm and were found up to a depth of 75 cm in the soil.

Nirula *et al.* (1952) have observed the larva of this species feeding on the roots of coconut, cassava, sweet potato, yam and colocasia. Studies also have been made on this species by Abraham and Chandy Kurian (1970); Sekhar (1958) and Mathen *et al.* (1974).

Leucopholis lepidophora Blanchard (Fig. 14)

Blanchard 1850, Cat. Coll. Ent., 1 : 158.

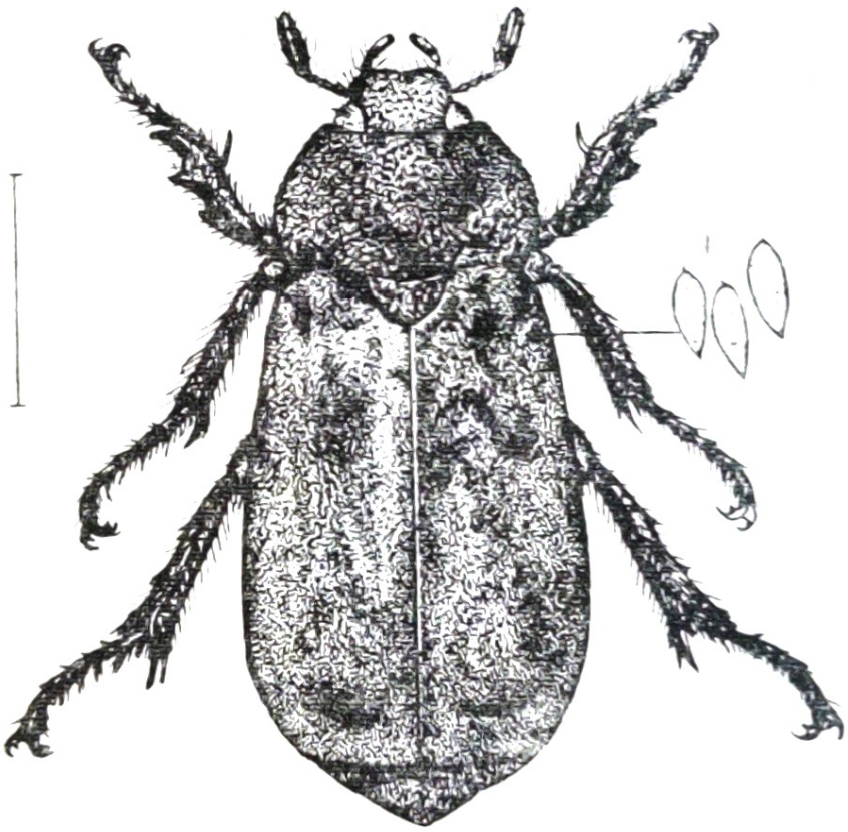


Fig 14. *Leucopholis lepidophora* Blanchard with scales magnified

The adult is a large beetle, oval, narrow towards both the ends, dark in colour covered with golden yellow oval scales all over the body (Fig. 14); rest of the characters similar to that of *L. coneophora*. Length 32–34 mm.

This species was collected in its larval stage along with *L. coneophora* and the larval habit was found similar to that of *L. coneophora*.

Leafmans (1951) reported that the natives of Nijverheid, Africa, attracted the beetles *Leucopholis rorida* F. by rubbing dried fruits of *Capsicum annuum* L. on stones, in the evenings but only males were attracted.

Schizonycha ruficollis Fabricius (Fig. 15)

Fabricius 1781, Spec. Ins. p. 39.

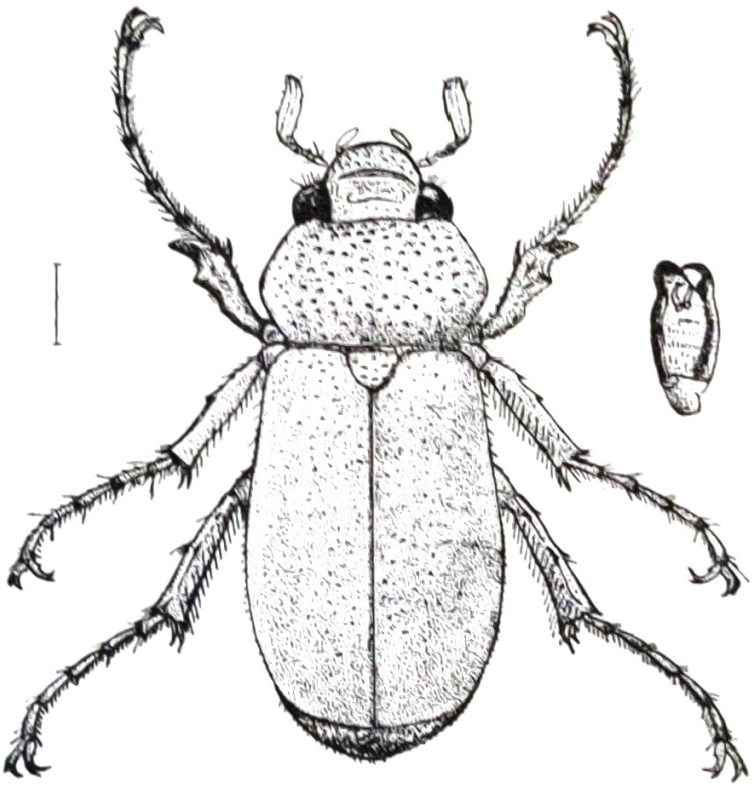


Fig 15. *Schizonycha ruficollis* Fabricius

It is shining rufocastaneous ; clypeus emarginate ; upper surface of the head roughly rugose ; third antennal segment beaded ; club in male is long, longer than 2nd to 7th segment ; punctation on the elytra closer and irregular ; fore legs long, tarsus more than twice as long as tibia, claw forked at the tip, outer narrow, inner thicker. Length 12–13 mm. Paramera Fig 15.

This species was very common all over the State and after the April rains large numbers were found feeding on tamarind (*Tamarindus* indicus) leaves during night. More were attracted to black light than to fluorescent light. The grubs were reported to feed on roots of *Prunus* (Mathur and Singh, 1960) and sugarcane (Kumar, 1971). The adults defoliate rose leaves (Roonwal, 1954) and grapevine (Batra *et. al.*, 1973).

3. Bionomics of *Holotrichia serrata*

A detailed study of the bionomics of *H. serrata* has brought out several facts on which an integrated method of control for this pest could be based. Several workers studied in detail the biology of other species of *Holotrichia* elsewhere (Davis, 1916; Hayes, 1923; Korschefsky, 1940; Schwerdtfeger, 1944; and Ritcher, 1958) where the normal life cycle is more than one year. Majumdar and Teotia (1965) worked out the biology of this species under North Indian condition. The work on the biology of other Indian species of *Holotrichia* are those of Gupta and Avasthe (1957); Srivastava and Khan (1963); Kalra and Kulshreshtha (1961) and Venkataramaiah (1969).

3.1 Egg (Fig. 16)

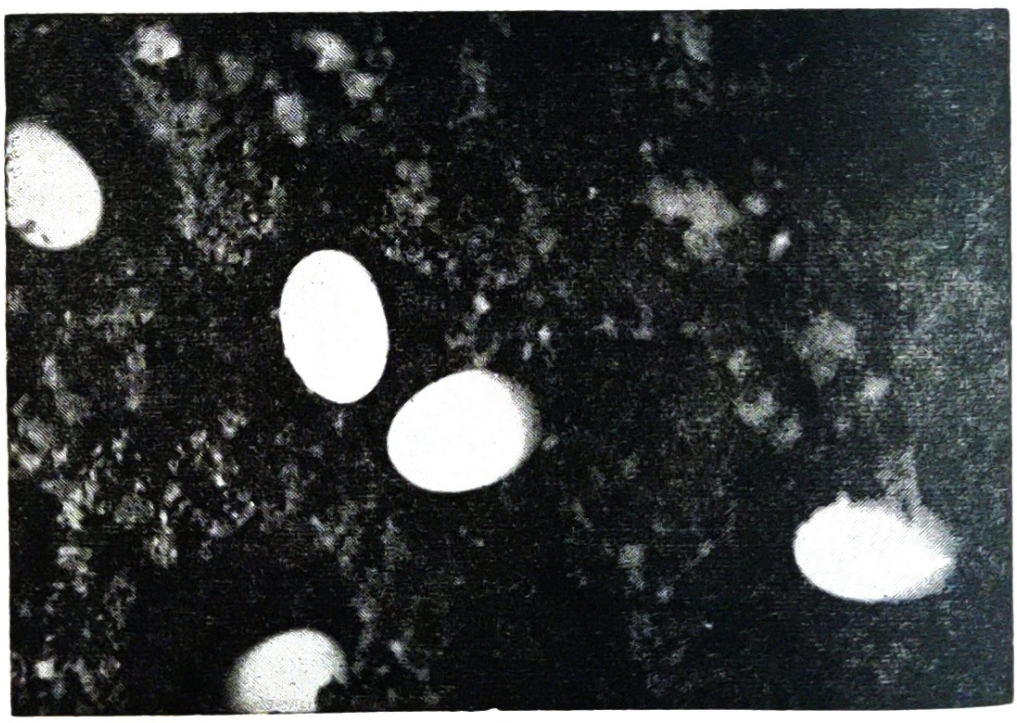


Fig 16. Eggs of *H. serrata*

Egg creamy white, oval when freshly laid and measures on an average 3 mm long and 1.7 mm broad. After 2 to 3 days the egg turns spherical, smooth, measuring 2 mm in diameter. In 6 to 8 days the chorion becomes slightly transparent towards one end and milky white towards the other and the developing embryo is visible with its cephalic appendages. When there is not sufficient moisture in the earthen cell enclosing the egg, it bounces up to 2 to 3 m, when it is dropped on a smooth surface from half to one metre height. If moistened, it easily breaks even if it is dropped from 25 mm height. Colour changes as the development advances and the egg swells up to 4 mm in diametre, one or two days before hatching.

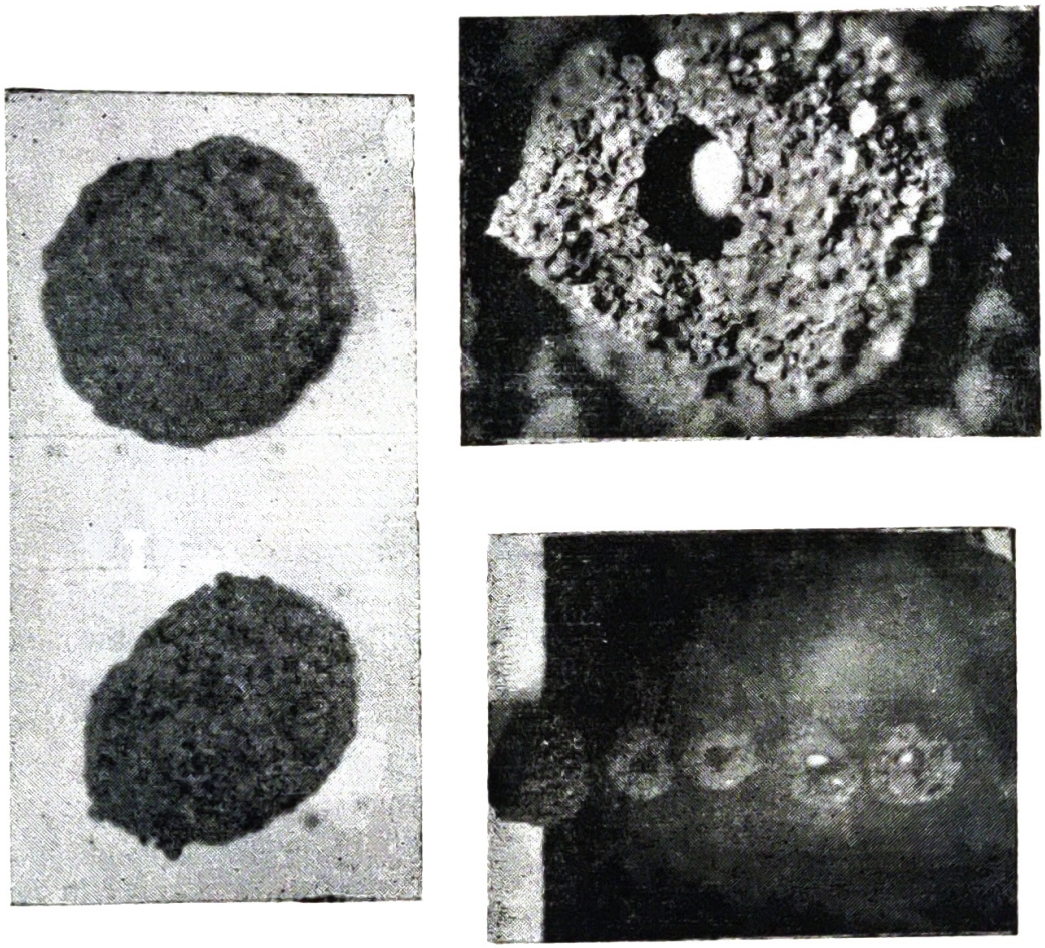


Fig 17. Earthen cells made by adult female *H. serrata* for egg laying. Left – Unopened earthen cells. Right bottom – Opened cells showing empty space, egg and larva inside the cell. Right top enlarged earthen cell with egg

Egg laying started, the day after copulation. Thirty nine unmated females did not lay eggs in 3 weeks of their adult life when they were separately enclosed immediately after the emergence. Egg laying was mostly done during day time. Two sets of 20 females each, enclosed for egg laying, showed that only those which were provided with soil during day time laid eggs normally and those which were allowed into the soil only during night did not lay eggs normally (Fig. 18).

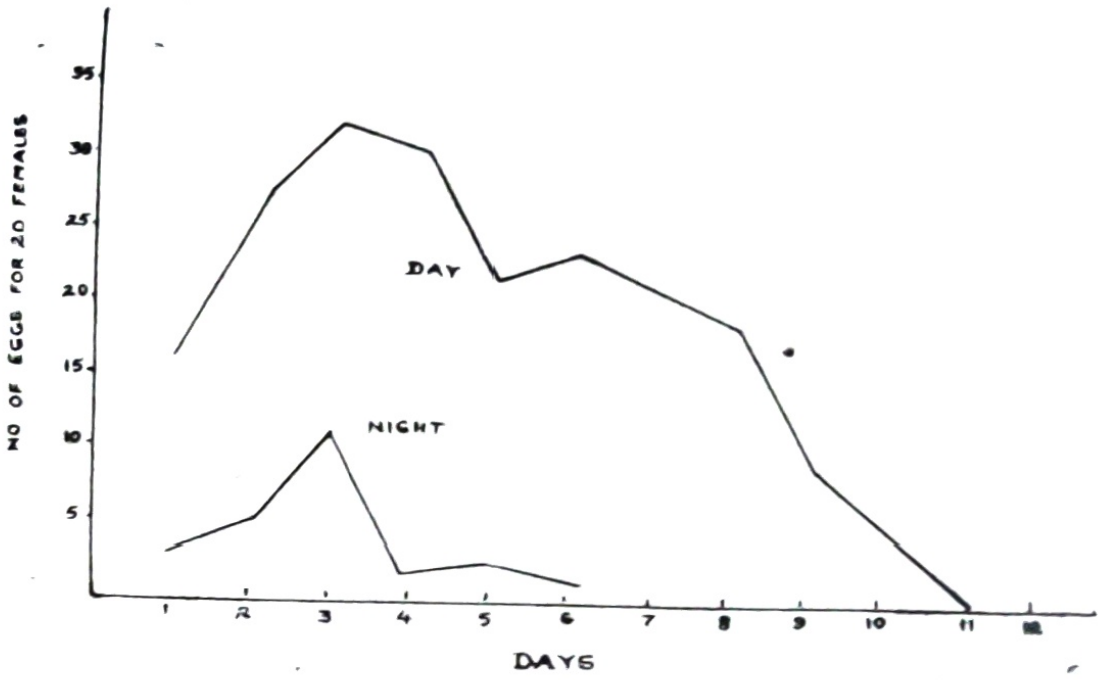


Fig 18. Egg laying pattern of *H. serrata* during day and night

On an average a female laid 26 eggs, the maximum and the minimum being 41 and 6 respectively, for a sample of 30 beetles observed during 1970, 1971 and 1972 (Fig. 19). A majority of the eggs were found between 8 cm and 18 cm depth in a sandy loam soil and were laid in earthen cells of 1 to 2 cm outer diameter (Fig. 17). There was one in each cell. Cells were at depths of 8 to 16 cm and provided space around the egg. A maximum of six eggs were laid by a female in one day under laboratory conditions. Egg laying was irregular, sometimes leaving four to six days gap between two egg laying days. There was sufficient space between the two egg cells inside the soil. There was no marked difference in the number of eggs laid by females collected from the field soon after emergence and females reared in the laboratory. There was also no marked difference between the

number of eggs laid by females fed before egg laying and those of non-fed females. Longevity of the female did not vary between those fed and non-fed.

Though egg laying extended over 3 weeks in some individuals, majority of the females laid more than 60 per cent of their eggs in the first ten days after succeesful mating. Individuals reared in the laboratory laid on an average 26 eggs per female compared to 26.7 eggs per female collected from the field. The average egg laying period of a female was 15 days, the maximum being 20 days under laboratory conditions (Fig. 19).

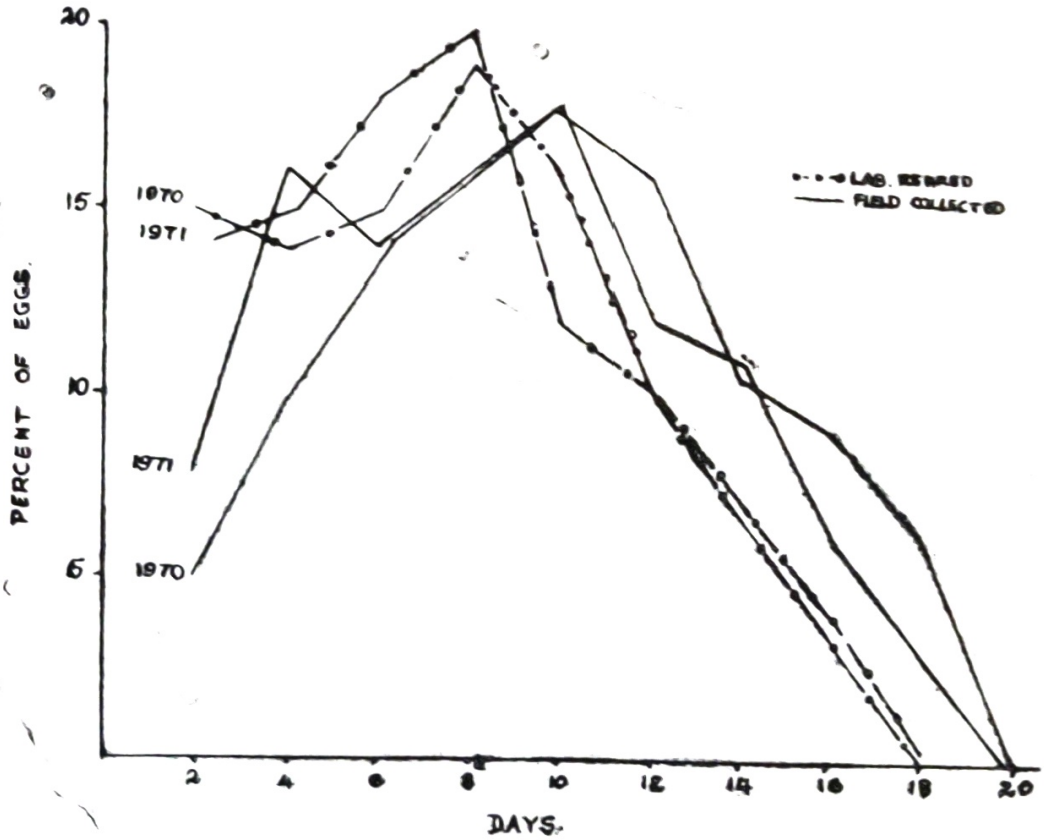


Fig 19. Fecundity of *H. serrata* From Laboratory reared and Field collected Beetles (Avarage of 15 beetles)

The first summer rains in April and May were crucial for adult emergence and egg laying. The adults did not emerge and lay eggs

unless there was some rain irrespective of availability of moisture in the soil during April and May. In the field survey the eggs were noticed as early as 2nd April and lasting up to June 16 depending upon the rains. Early rains in February or early March did not induce adult emergence and egg laying as the gonads did not fully ripen until the last week of March under Bangalore condition (Fig. 44). Egg laying was completed before first week of May in all the 3 seasons under laboratory conditions. Eggs of this species were noticed in the field at Ranchi from February to July by Majumdar and Teotia (1965). In Bangalore the egg laying started in the commencement of April and it was completed before the close of May depending upon the rains. Majumdar and Teotia (1965) found egg laying from commencement of April to the close of July under laboratory condition, extending over a period of 4 months compared to two months under Bangalore condition.

According to Majumdar and Teotia (1965) a single female laid a maximum of 92 eggs and a minimum of 24 eggs, the average being 64.4 eggs during its life time under laboratory condition, whereas the field collected female laid larger number, the maximum and the minimum being 122 and 79 respectively. This variation in the fecundity is perhaps due to longer adult life under Ranchi condition and shorter adult life under Banglore condition.

3–2 Influence of hosts of adults on oviposition behaviour

The egg laying pattern of the adults varied with the distance from the host plants of the adults. Forty eight per cent of the eggs were found in 5 m distance from the host plant (5 to 7 m ht) and this trend progressively decreased as the distance from the host plants increased, the percentage being 25.1, 17.7, 9.1 at 10, 15 and 20 m from the host plant respectively.

Incubation period : The time required for the incubation of the eggs varied from 10 to 12 days at room temperature (27°C to 34°C) (Fig. 20). At lower temperatures hatching was delayed. Out of twenty eggs each kept at 4°C, 10°C and 15°C for 5 weeks and then removed to room temperature, no hatching was observed in case of eggs kept at 4°C and 10°C, and only 13 hatched out of 20 from the lot kept at 15°C. However, only 3 larvae survived. Further development of these 3 survivals was normal under natural condition. The eggs hatched to the extent of 82 per cent under laboratory conditions

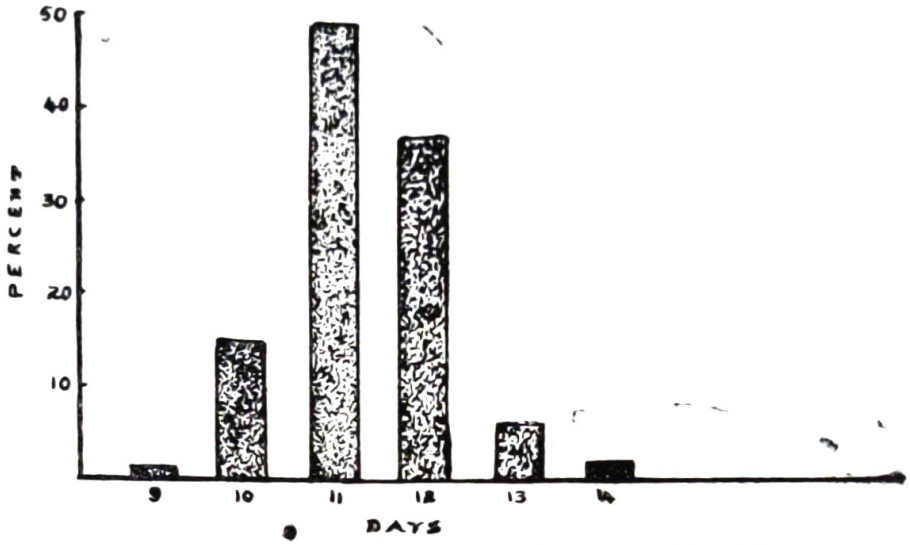


Fig 20. Incubation period of *H. serrata* (27°–34°C)

According to Majumdar and Teotia (1965) the incubation period varied from 8 to 13 days and only 52.2 per cent hatched on an average under laboratory condition at Ranchi.

3–2 Larva (Fig. 21)

First instar: Immediately after hatching, the grub is creamy white in color and measures on an average 10.8 mm in length and

Fig 21. Larva of *H. serrata*

2.7 mm in width, head capsule 2.1 mm. The head turns brown in a few hrs and the grub becomes active in about 4 hrs. The first stage larva comes out of the cell if there is sufficient moisture. Under drought conditions it remains inside the cell until favourable conditions occur.

In an observation made on the drought tolerating capacity of the first stage larva it was found that the larva can survive for more than 110 days within the earthen cell if enough moisture was not available. The larva did not survive for more than six days under saturated conditions. This observation was made under laboratory condition in 60×60 cm cement pots when a number of earthen cells containing eggs were kept at different depth under varying condition of moisture content. Though nearly 50 per cent of the grubs were dead under drought condition, still the remaining grubs were not affected by prolonged drought, as they completed their life cycle when allowed to normal condition.

The average duration of the first instar under laboratory condition was 30.2 days for 76 grubs that reached second instar in three seasons, the minimum and the maximum being 23 and 36 days respectively (Fig. 22).

Second instar: The second instar grub measures on an average 28.0 mm in length and 7.0 mm in width and the head capsule

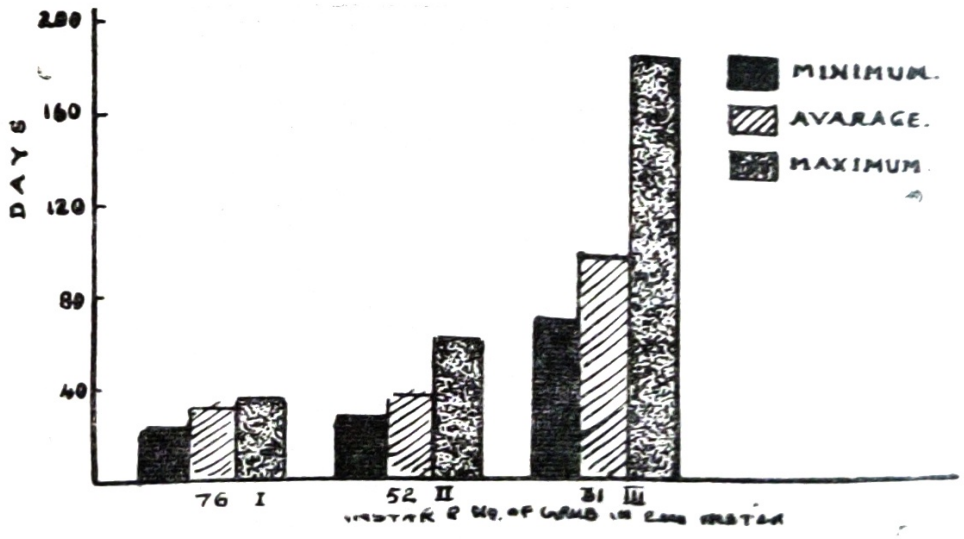


Fig 22. Duration of different instars of *H. serrata* (76 52 and 31 are the Nos. of individuals observed)

measures on an average 5.6 mm. The shape and colour resembles the first instar but the last abdominal segment becomes more swollen and darker.

The duration of second instar on an average was 35.8 days, the minimum and the maximum being 26 and 62 days respectively (Fig. 22). Out of 76 grubs reared from first instar to second instar, only 52 survived to the third instar.

Third instar: The third instar is slightly yellowish, creamy white in colour, measuring on an average 47 mm in length and 12 mm in width, the head capsule is 7–8 mm in width. The third instar is active root feeder, with powerful mandibles, antennae 5 segmented, the last segment with one dorsal and two ventral sensory spots (Fig. 24). Thoracic segments distinct, the fore legs shorter, the hind longer and the middle pair in between. The first pair of spiracles

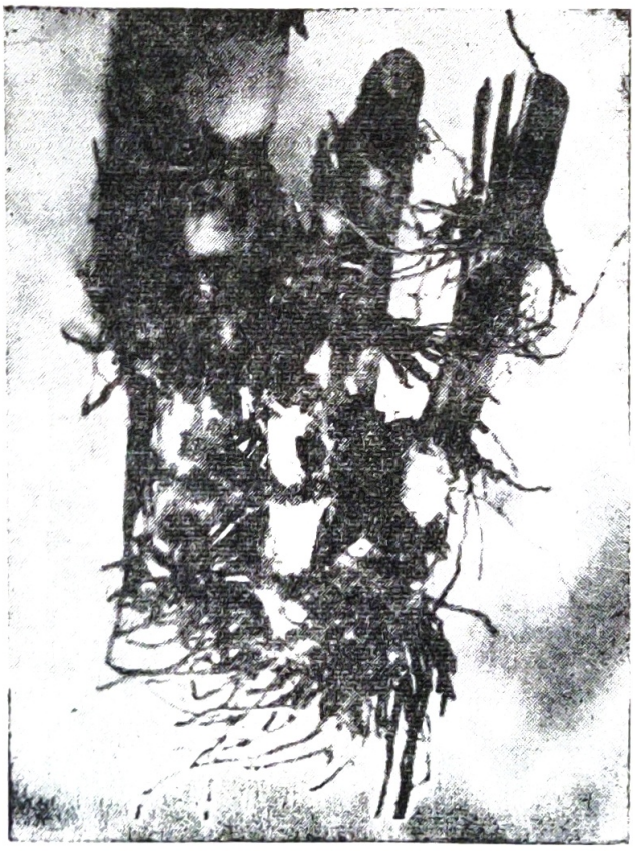


Fig. 23. A—Sugarcane showing the roots damaged by grubs and holesmade by pupating larva

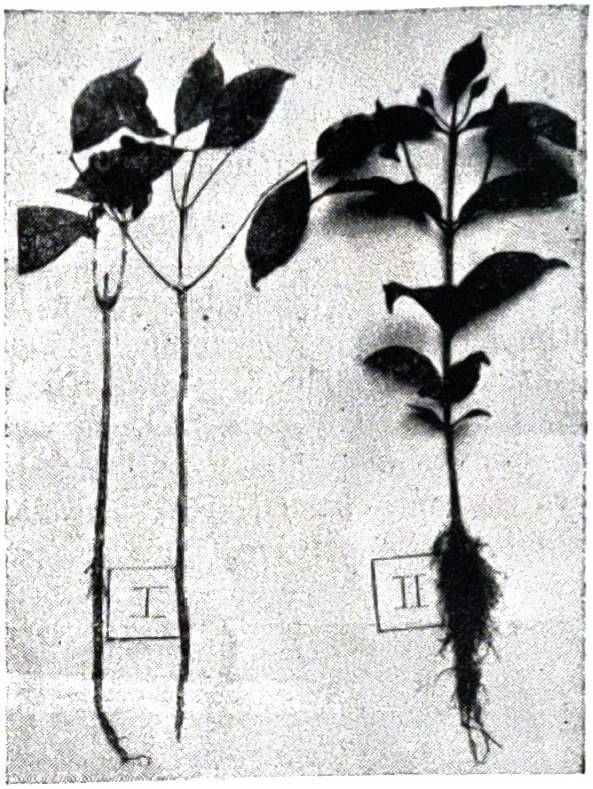


Fig. 23 B—Newly transplanted coffee seedlings: I, roots completely eaten by grubs ; II, roots intact

Fig. 23 C—Sugarcane field showing seedings damaged by grubs

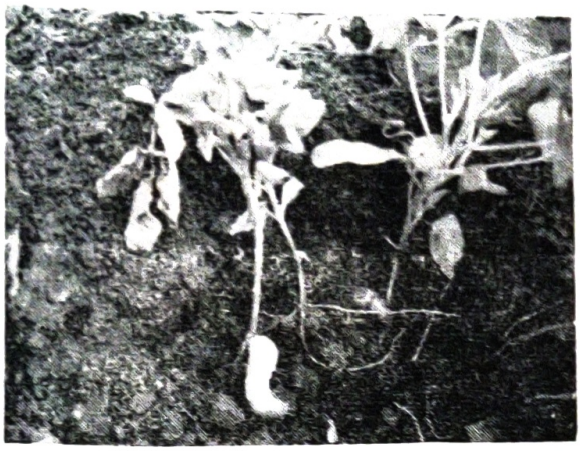


Fig. 23 D—Cotton seedlings damaged by grubs

Fig. 23 E—Maize damaged by grub

Fig. 23 F—Tobacco field showing patches with plants killed by grubs

present on the posterior margin of the prothorax and the remaining 8 pairs on the first 8 abdominal segments, all spiracles with respiratory plates completely surrounding the bullae. The anal slit is 'Y' shaped with its arms longer than the stem.

The average duration of third instar was 102.9 days for 31 grubs, the minimum and the maximum duration being 72 days and 188 days respectively (Fig. 22). A few third instar larvae were found to remain in the soil without undergoing pupation in the first year and then pupated early in the next season in August and September under field conditions, but these adults remained in the soil till next April. Out of 52 grubs reared from second instar to third instar only 31 survived to pupation.

The average period of the first to third instars at Ranchi was found to be 31.2, 36.5 and 81.0 days respectively (Majumdar and Teotia, 1965).

Certain structure of the larva are of taxonomic importance and several workers have classified the melolonthine beetles on the larval characters (Hayes, 1925; Boving and Craighead, 1931; Gardner, 1935; Emden, 1941 and Ritcher, 1966). Gardner (1935) and Ritcher (1961) described the 3rd stage larva of this species but did not provide detailed descriptions of all the structures of taxonomic importance. A detailed description of the labrum, mandibles, maxilla, epiphrynx, cranium including epicranium and clypeus and rasterof the 3rd instar larva is given below with the help of suitable diagrams.

Labrum (Fig. 25)

The labrum is slightly asymmetrical, somewhat longer than the clypeus, but only slightly narrower, leteral ateral margins are convex and the apex distinctly projects and is somewhat crenate. Across the labrum is a more or less well marked median transverse and complete ridge (Trmr), which is irregularly wrinkled on its broad rounded crest and anterior to this edge, approximately parallel with it, are two similar but shorter and incomplete ridges, one in front of the other. The setae are distributed as follows. The apical projection (AP) has two short to moderately long, stiff setae (a) on eace side;

lateral to setae Trmr and along the lateral margin are 4 fairly long setae (b) and on each side in front of the anterior incomplete ridge near the lateral margin is one long seta (c); in front of the median

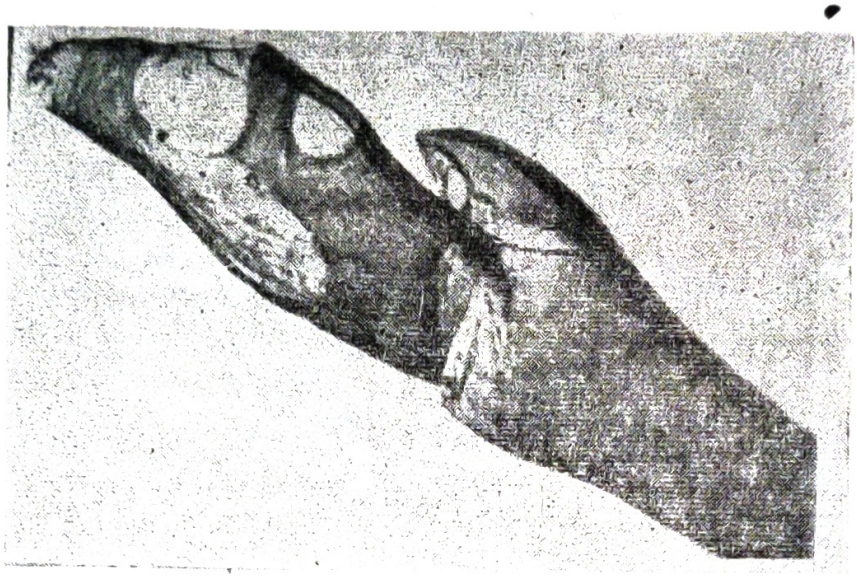


Fig 24. Last segment of larval antenna of *H. serrata* showing the dorsal and ventral sensory spots

transverse complete ridge there are on each side two long setae (d); behind the median transverse ridge are a series of six moderately long setae on each side (e).

Clypeus (Fig. 25)

The clypeus is trapezoidal in general outline, anteclypeus (Acl) is whitish and naked, post-clypeus (Pcl) is slightly larger and darkly sclerotized. On each side of the post-clypeus is an anterior and a posterior lateral seta, and between the anterior lateral and the sagittal line is one long seta on each side.

Epipharynx (Fig. 28)

The epipharynx situated under the labrum and clypeus. The boundary towards the pharynx is marked by the transversely curved transparent crepis (Crep). The plegmatia (Plg) are well developed, consist of 16 to the right and 14 to the left, transverse plegmata gradually diminish in length anteriorly and posteriorly. The acanthopariae (Actp) carry 16 to the right and 14 to the left. Chetopariae

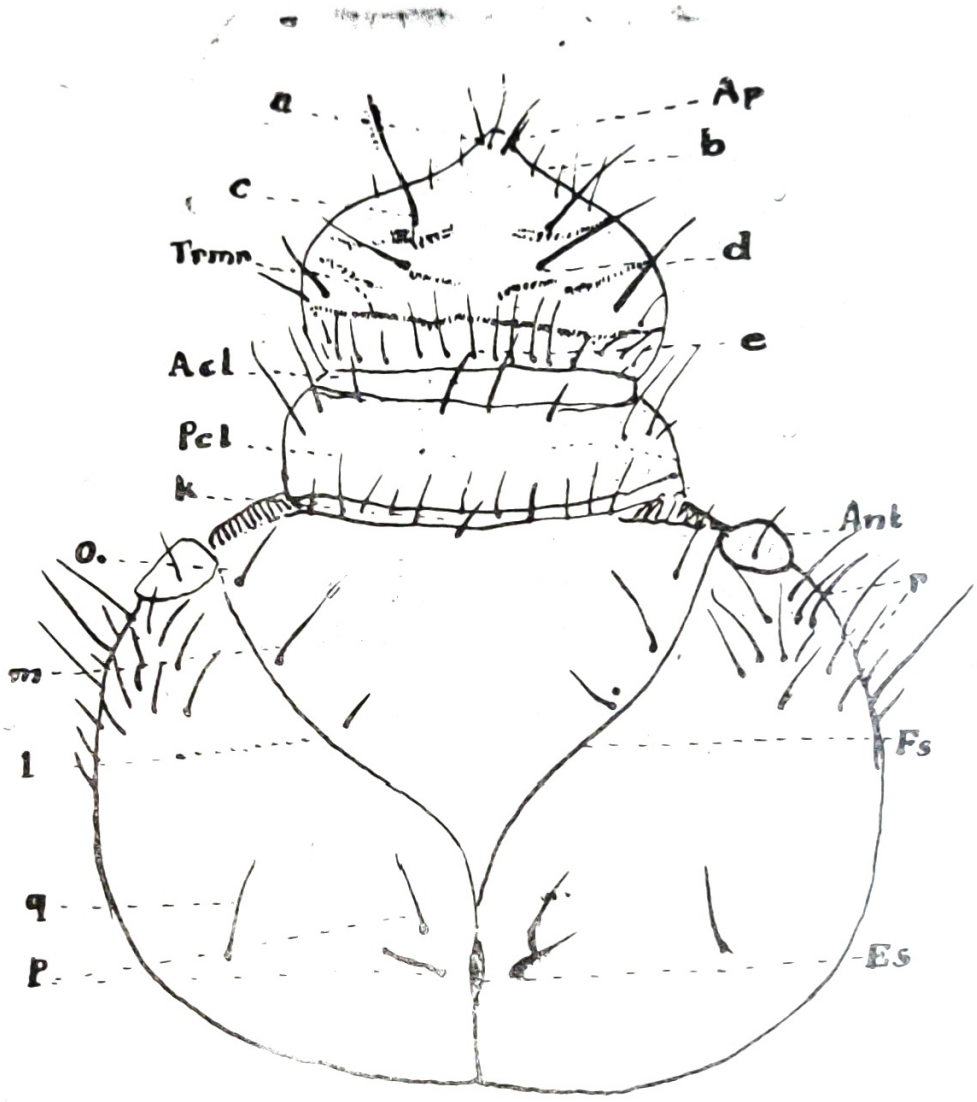


Fig. 25. Cranium of *H. serrata* larva (diagrammatic) (a to e – setae of labrum; k to o – setae of frons; p to r – setae of epicranium) Acl, anteclypeus; Ant, ringshaped support of Antenna; Ap, apical projection of labrum; Es, epicrenial suture; Fs, frontal suture; Pcl, post clypeus; Trmr, Transverse median ridge of labrum.

(Chp) are large, with strong straight setae nearest the pedium (ped) and gradually weaker and shorter setae towards the plegmata. The epizygum (Ez) is not connected with zygum (Z). Along the inside of

Zygum is a single curved series of 6 dark, large punctures, and interspread between them is an almost similar number of much smaller punctures. The helli (Hi) are strong, curved, dark, arranged in three arched concentric series with 10 in the front series and 9 each in the inner group.

Pedium (Ped) is long, the laeotorma (Laeot) is dark and strong, with distinct pternotormal projection (pternot) with both apotormal (Apot) and epitormal (Epit) prolongations between which are two strong setae.

The dexiotorma (Dexiot) is dark and slender. On the inner end of laeotorma there are eight Laeophabae (Lph) crowded closely together in a straight longitudinal series. Between the laeotorma and nesium externum in front of the crepis are two large and ten small Crepidol punctures.

Cranium (Fig. 25)

The cranium is slightly narrower than the prothorax, about 7mm in breadth and about 5 mm in length. The clypeo–frontal suture is well marked. The frontal suture (Fs) is distinct. The epicranial suture (Es) is about 1/3 the length of one of the frontal sutures and has anteriorly a small, lanceolate, slightly impressed brownish enlargement.

Mandibles (Fig. 26)

The mandibles are strong, the scissorial part (Sc) has a straight cutting edge, and a sensorial pit on its dorsal side. The molar area of the right mandible (c) is trilobed with the lobes increasing in size towards the heel or base (Cx). The left mandible (Fig. 26c) molar area is bilobed with the anterior lobes strong and shielding the lower. A well developed brush of long bristles is found at the base of both right and left molar parts. In the dorsomolar region of the right mandible are 9 setae arranged in single patch. In the dorsomolar part of the left mandible (Dmr) (Fig. 26A) only an oblique series of 5 setae are present. A number of sensory punctures are present on the dorsolateral region of both right and left mandibles without any hair. On the ventral lateral carinae (Vlc) is a longitudinal series of 10 setae.

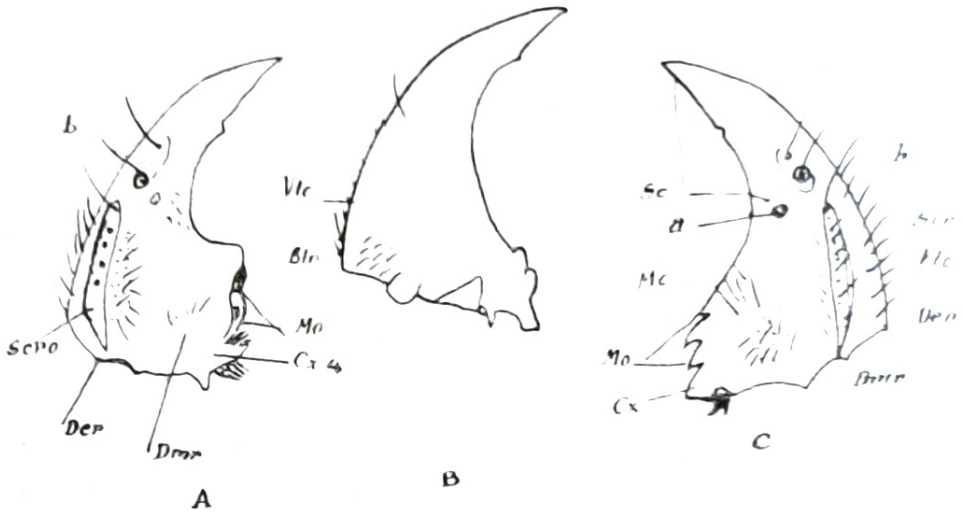


Fig 26. Left and right mandibles of *H. serrata* larva (diagrammatic) : 26A–laft mandible dorsal view. 26B–right mandible ventral view ; 26C–right mandible dorsal view. Blr, baso–lateral region ; Cx, Calx on right mandible ; Cx–U, Calx with uncus on left mandible ; Der, dorso exterion region ; Dmr, dorsomolar region ; MC, manducatorial part ; Mo, molar structure ; Sc, scissorial part, Scro, scrobis ; Vlc, Ventro–lateral Carina

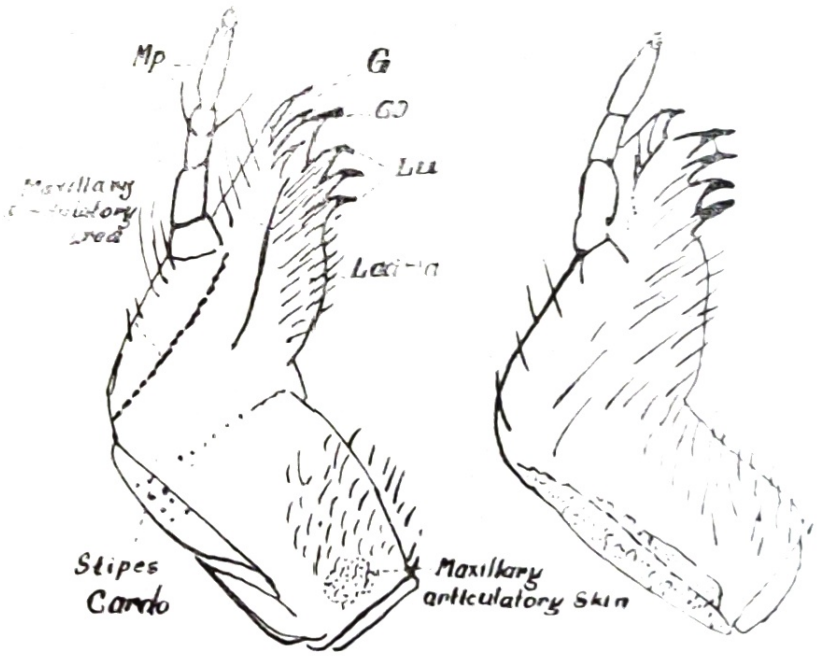


Fig 27. Maxilla af *H. serrata* larva (Diagrammatic), Leftdorsal view ; right, ventral view
G–galea ; GD–uncus of galea ; Lu–unci of lacinia ; MP–Maxillary palpus

The baso–lateral region (Bir) (Fig. 26B) carries a patch of 8 setae.

Maxilla (Fig. 27)

Maxilla with proximally fused galea and lacinia and free distally Maxillary palp 4 segmented. the last segment with a whorl of sensory setae at the tip (Fig. 27A). Second segment has two long setae on its

Fig 27A. Larval maxilla showing the maxillary palpus with a whorl of sensory setae at the tip and Galea and lacinia showing unci

dorsolateral position. A row of 14 truncate stridulatory teeth are present on the dorsal side of stipes ; galea has one uncus and 3 stout setae ; lacinia with a longitudinal row of 3 stout unci, on either side of which, six stout setae are present. Cardo is with 8 punctures on its dorsal surface.

Raster (Fig. 28)

The tenth abdominal segment on its ventral side, the raster, has a longitudinal group of pali on either side of a median, bare region,

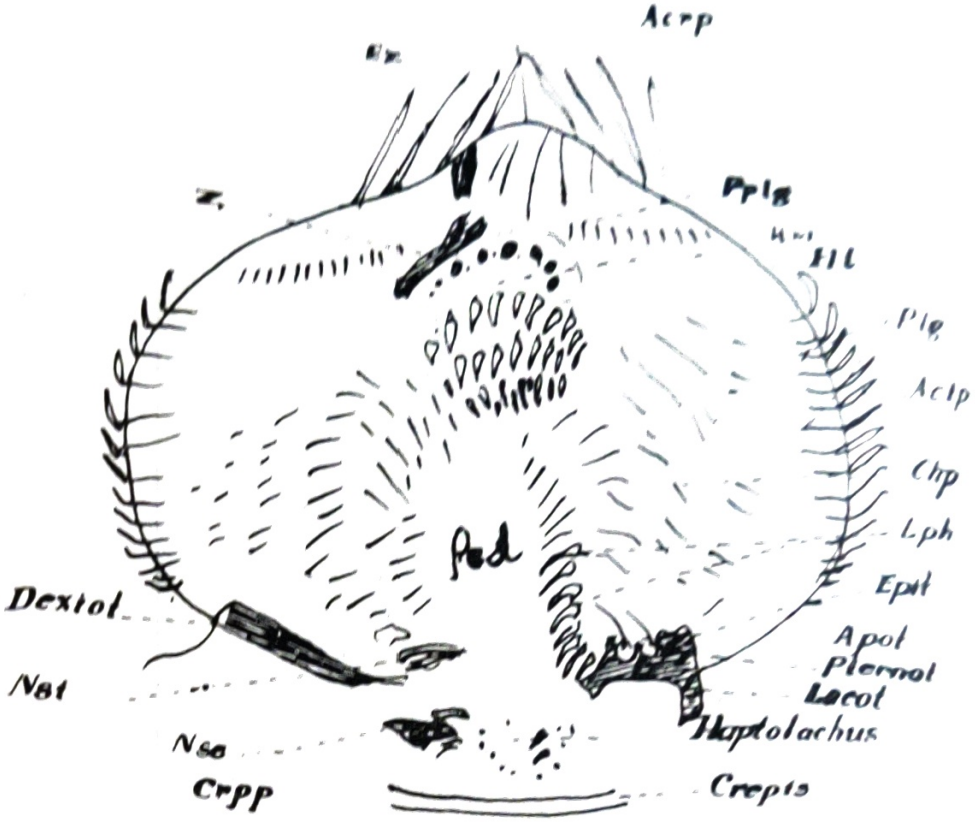


Fig 28. Epipharynx of *H. serrata* larva (diagrammatic). Acrp, acroparia; Actp, acanthoperia; Apot, apotorma; Chp, chaetoparia; Crep, Crepis; Dexiot, dexiotorma; Epit, epitorma; Ez, epizygum; Hl, helus; Hm, haptomerum; laeot, laeotorma; Lph, Laeophoba; Nse, nesium externum; Nsi, nesium internum; Ped, Pedium; phob, phoba, plg, plegmatium; plg, Proplegmatium; Pternot, Pternotorma; Z, Zygum

the septula. Each palidium consists of a singel row of 20 pali (Fig. 29A). The septula is long, narrower anteriorly and broader posteriorly. The tegillae are well developed, covering venter between the barbulae (Brb) and the pelidia.

3.3 Food habit of the larva

The first stage larva fed on the organic matter available in the soil but whenever it encountered live roots it preferred roots to organic matter. Experiments wlth various foods like farm yard manure, gingelly cake, cotton cake, poultry feed, groundnut cake, coconut cake, honge oil cake, fish meal, mixed in soil separately and given to

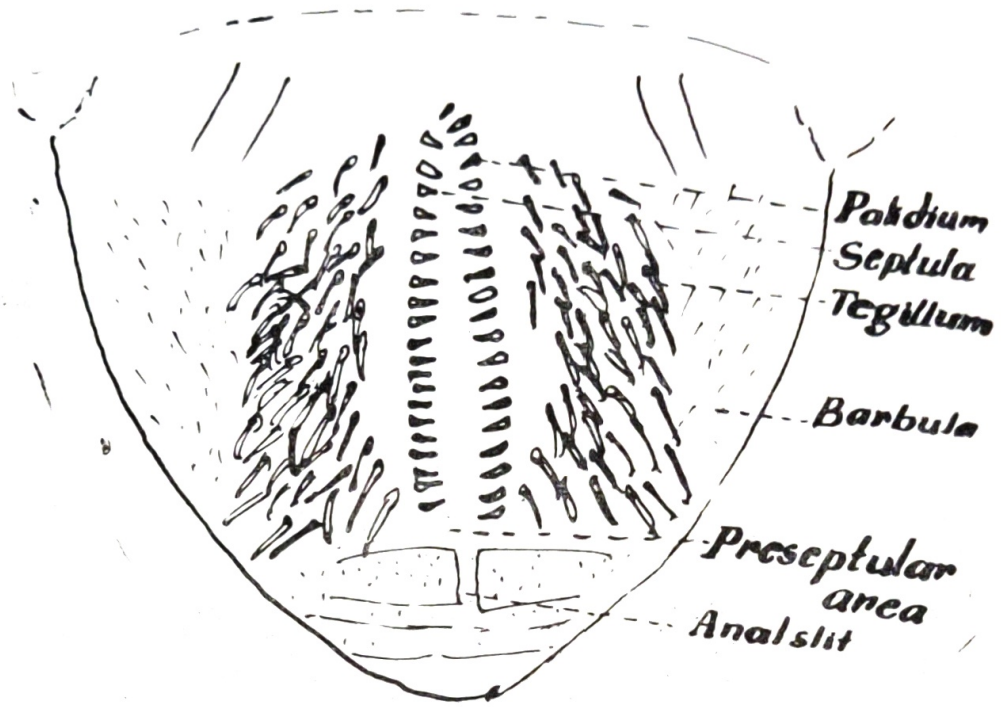


Fig 29. Ventral view of the tenth abdominal segment with raster of *H. serrata* larva (diagrammatic)

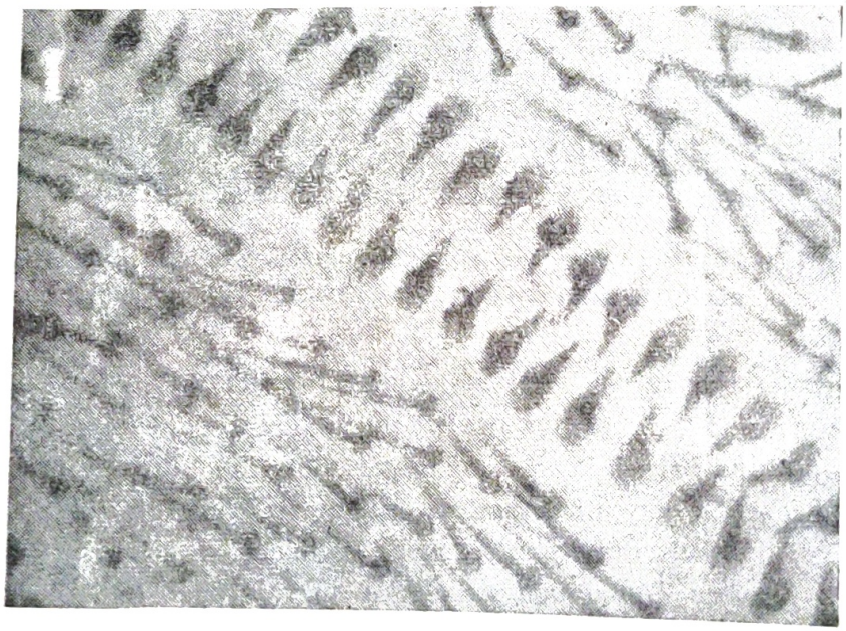


Fig 29A. Venter of tenth abdominal segment with two rows of palidia

first instar grub did not allow them to develop except in the case of poultry feed and farm yard manure where the grubs developed to the 3rd stage but did not pupate. The growth was very slow in poultry feed, 42 days for the first stage and 79 days for the second stage larva. Farm yard manure mixed in the soil was a satisfactory medium for the first stage larva when it developed normally, but the second stage larval growth was retarded and took 57 days to moult. However, the grubs did not pupate. The first stage larva survived for 22 days in all the food media, thereafter the death started, the first to die were in the honge oil cake and fish meal. In all the above food media, in presence of sprouting maize, the development was normal and reached pupal stage.

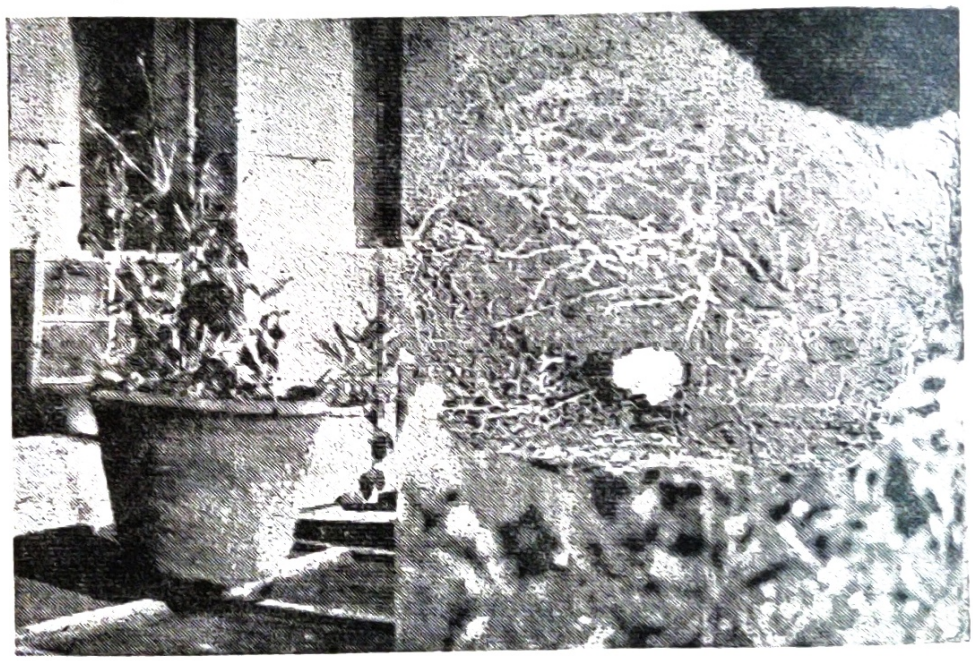


Fig 30. *Galinosoga parviflora* Cav., Left, potted plant with grubs. Right, plant removed from the pot to show roots and grub of *H. serrata*

Among the cereals, millets, pulses, vegetables, oil seeds and cucurbits tried as a source of live roots for the developing larva, groundnut and French bean were found preferred hosts as they were first attacked when all occurred together. However, there was no difference in their development among the different hosts that were tried. A weed *Galinosoga parviflora* Cav. (Fig. 30), was found tolerant to the attack of grubs during the course of this investigation. The weed, alone and in combination with several accepted hosts was

not affected by the attack of root grubs. Grubs reared exclusively in the pots in which this weed alone was grown took a longer time to pupate (February), whereas grubs, reared in pots where the weed and other host plants were grown together, pupated normally (December). The weed did not suffer as a result of feeding by grubs as it put forth numerous roots and at the same time the grub also completed its life cycle. A single weed survived the feeding by six grubs. Other plants would have been killed by six grubs.

Fig. 31. Sunflower, *Helianthus annuus* Linn., rear rows of pots not damaged by grubs. Front row of groundnut plants completely damaged by grubs (*H. serrata*)

Under natural condition no plant species was found to be completely resistant to the attack of the white grub, although some species like sunflower *Helianthus annuus* Linn. could withstand the attack, provided enough moisture was available and the tap root was not damaged (Fig. 32). Heavy incidence of the grub in localised patches was mainly due to the presence of adult host plants like, neem, acasia, cassia etc. The grubs fed on roots of any plant species under varied conditions of soil except under puddled conditions.

Perennial trees like guava, citrus, peach etc. were found killed by the grubs, not because of grubs feeding on roots but because the stem was debarked at depth of 12 to 15 cm from the surface, in the absence of other roots around the base of such trees. An eight year old guava orchard of six acres, belonging to the Department of Horticulture, Karnataka, at Gundlupet (Mysore District) was completely destroyed? as a result of *H. serrata* grubs feeding on the underground bark around the stem during the year 1973–74.

Fig 32. Sunflower stem with roots. Left : majority of secondary roots eaten but tap root not damaged ; right ; Tap root damaged, secondary roots intact

When sorghum, onion, garlic and ragi were sown in rows alternatitely in a grub infested field, all the crops were affected, at Sidlaghatta, Kolar District.

3.4 Effect of temperature moisture and soil on the larva

Water logged conditions do not favour the development of grubs in spite of the presence of live roots. Experiments conducted in 60 × 60 cm cement pots (Fig. 35) showed that under saturated condition the grubs did not survive for more than seven days whereas under drought condition grubs survived for 112 days and they were able to feed and pupate when returned to normal condition, although there was 60 per cent mortality and they took a longer period to pupate (February) than normal grubs required (December).

In nature, continuous rain or water logged condition in a fallow land for 3 to 4 days during August–September forced the grubs to come to the surface keeping the head and abdominal tip immerced in the soil and the abdomen slightly exposed. As the water receeded, large number of crows and other predacious birds were found picking these grubs. When soil was puddled, and left to dry certain per cent

of grubs managed to survive by constructing earthen cell to tide over the unfavourable condition and revived when normalcy occurred.

The third instar grubs kept at constant temperature of 4°, 10° 15°, 20°, 25° and 30°C, in temperature control chambers, did not survive for more than four weeks exeept at 20°C and 25°C. The death was quicker at 4°C and 10°C as they did not survice for more than 17 days and 21 days respectively whereas at 15°C they survived for 33 days. At 20°C, 50 per cent of grubs found healthy lying in cells for 136 days, whereas at 25° and 30°C they constructed cells but did not pupate and died within three months.

Grubs were found to exist in different types of soils except in hard gravelly soil. Contrary to the belief that the grubs thrive well only in sandy loam soils, it was observed that they can equally well establish in black cotton soil as was found in northern districts of Karna taka (Fig. 23F) as well in clay soils of areca gardens. However, in laterite soils of heavy rainfall area, and at high altitude this species occured in small numbers compared to *H. nilgiria and H. sculpticolis*, In Mysore districts, at the foot of B. R. Hills in Chamaraja Nagar Taluk it was a major pest on several cultivated crops, but at the top of the hills in coffee plantations, it was very minor pest compared to *H. nilgiria*. Similiar situation was observed in the coffee growing districts of Chickmaglore, Hassan and Coorg.

3.5 Movement of the Grubs

Vertical movement : Observations made on the vertical movement both under controlled condition and in the field showed that grubs moved downward as the top soil began to dry and moved to the top under saturated condition. The movement of the grub up and down was directly related to the moisture content of the soil. The maximum depth at which the grubs were found under laboratory condition was 72 cm. Samples taken once in a month at random in the heavily infested fallow land at Hoskote kodi (near Bangalore) from June to January during 1971–72 showed that during the month of June, the grubs did not go beyond 20 cm, the maximum number being at depth between 10–20 cm. During the month of July and August only 8 per cent of the grubs were found at 20–30 cm depth and 81 per cent confined to 10–20 cm. depth. During November–January nearly 50 per cent were found at 20–30 cm depth and

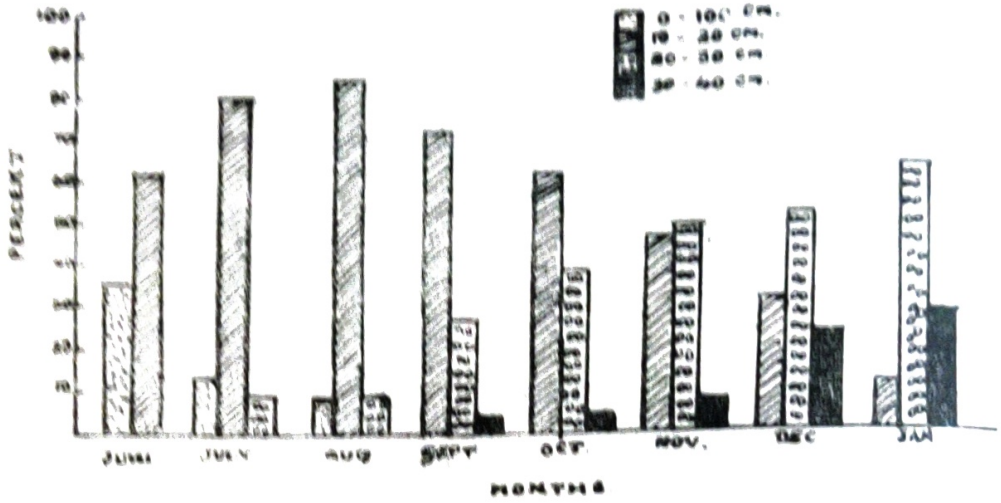


Fig 33. Percent of grubs (*H. serrata*) at different depth of soil

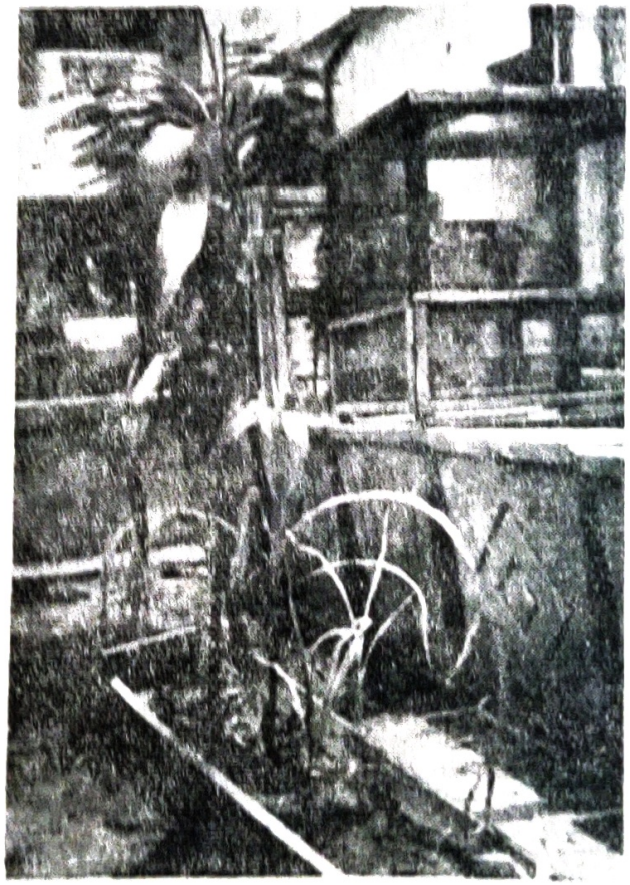


Fig 35. Wooden trough (bottom); 60 × 60 cm cement pots and cages used in the study of horizontal and vertical movement of *H. serrata* larva

about 20 per cent between 30–40 cm depth (Fig. 33). The maximum number of pupae were found at a depth ranging from 20–40 cm.

Horizontal movement: The horizontal movement of the grubs was observed both in the field condition and under the laboratory condition. Under field conditions fifty, third instar larvae were liberated in a 20 m^2 fallow ground free from grubs and without a crop. One week later 22 grubs were recovered at an average distance of 2.4 m from the starting point indicating an average lateral movement of 34 cm a day.

In another experiment six, third instar larvae were placed in one corner of a 5 metre long and 30 cm wide wooden trough (Fig. 35). Maize was sown at one metre intervals, 5 days prior to liberation of the grubs. It was found that seedlings one metre from the point of liberation of the grubs were damaged on the 3rd day after 48 hrs of liberation. Seedlings 2, 3, 4 and 5 metres away were damaged on 7th, 13th, 17th and 24th day respectively. Only two grubs reached the other end of the box, a distance of 5 m in 23 days, covering 21.7 cm a day on an average indicating that the lateral movement of grubs depends on the availability of live roots in third instar.

Gupta and Avasthy (1957) observed movement of *H. consanguinea* larvae downward and upward in the morning and evening hrs depending upon the temperature but Kalra and Kulshreshtha (1961) did not find this type of movement.

3.6 Density and Distribution of grubs

Weekly field observations taken for the population of different stages of the larva during 1971 and 1972 showed that the active last instar grubs ceased to exist beyond 4th week of February (Fig. 34). Therefore the month of March is free of active grubs of this species under South Indian conditions. Some grubs may remain in the earthen cells before pupation during March but they are not in an active feeding stage. Majumdar and Teotia (1965) found the grub of this species throughout the year, the maximum being during June-August.

The distribution of grubs in the field is closely related to the presence of host plants and the existence of the pest in the previous season. Since the adults do not go too far from the place of emergence for egg laying, more grubs are concentrated in a 20 metre

radius from the host plant. Fields bordering to the roads, channels and uncultivated area had more grubs towards the bund and the numbers progressively decreased towards the centre.

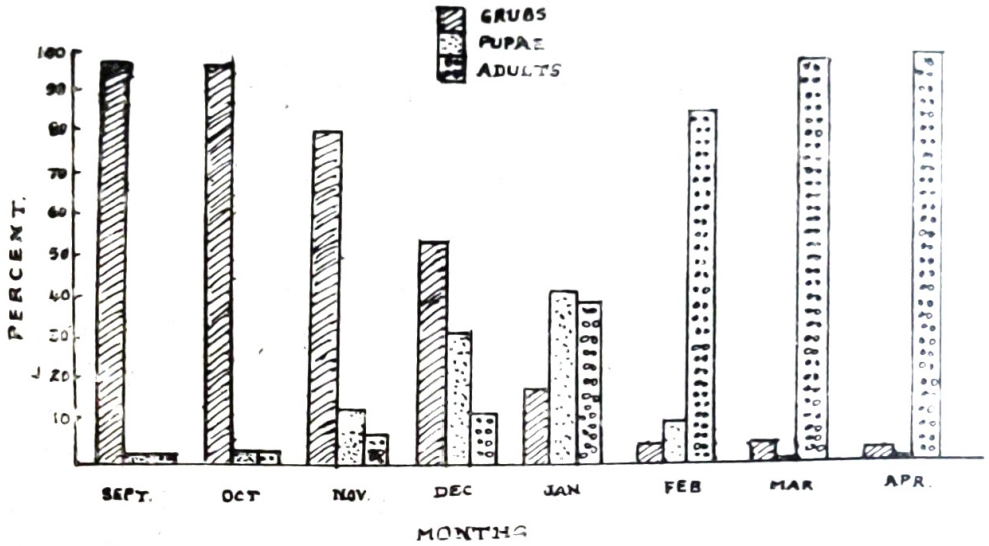


Fig 34. **Percent of grubs, pupae and adults in the soil during different months** (1971-72)

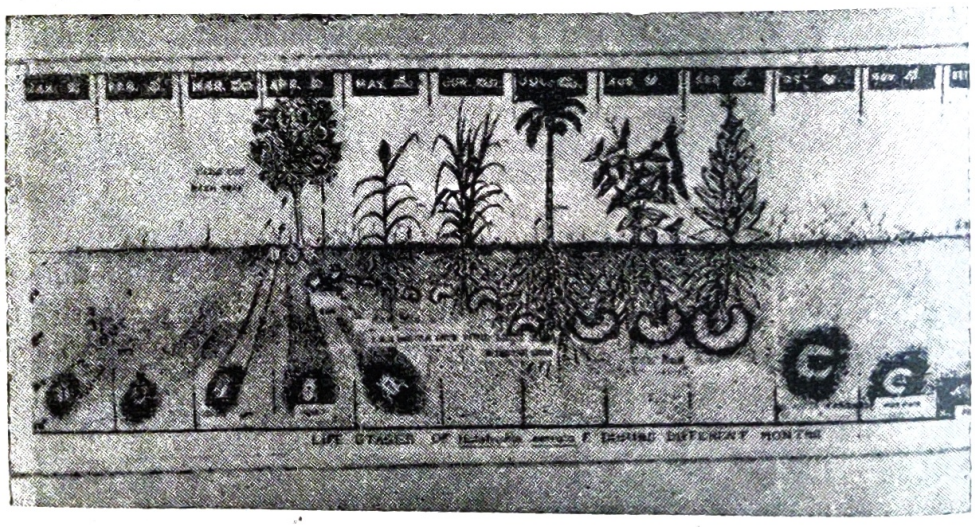


Fig 34A. Life stages of *H. serrata* during different months

Population samples taken at Thondavdi, Mysore District and Hospet, Bellary District at monthly intervals showed the first instar from April first week to July 2nd week; 2nd instar from April last

week to September 2nd week and the 3rd instar from May 3rd week up to the end of February. A small percentage of grubs skipped to the 2nd year. These grubs pupated early in September and remained in the soil as adults till the next summer rains.

The number of grubs per square meter varied depending upon the adult host plants, the cultivation practices and the type of the crop. The highest percentage of grubs were found towards the perifery in the infesied field and the number greatly decreased towards the centre. depending upon the host plants of adults on the bund and the previous year infestation. In some instances upto 37 grubs have been observed per square meter accounting for more than one hundred thousand grubs per acre. Under a single sugarcane clump upto 28 grubs have been recovered (Fig. 36) during July-September. Prasad and Thakur (1959) recorded 4 to 22 grubs of *H. Consangunia* per clump during

Fig. 36. Sugarcane clump showing grubs damaging the roots

September. Martorell and Goud (1965) stated that white grubs cause reduction of 15 to 20 tonnes of cane per acre when infestation range from 10,000 to 20,000 grubs per acre.

3.7 Sampling technique for grubs

While several methods were available for sampling the grubs for survey and surveillance, the one adopted by the author for the first

Fig 37. Soil sampling for grubs

instar grubs. 3 to 4 weeks after the first rains was found to be more suitable for sampling of large area. A sieve 60 × 45 cm wide and 10 cm depth made up of wire gauge with 3–4 mm mesh(Fig. 38) similar to the one used for sieving sand for construction, was used to extract the grub. A shovel and a wooden square board cut to the width of shovel, were used to take the samples. The wooden board was held pressed to the soil with one leg and soil was cut to a desired depth on all the four side with the help of shovel and lifted from one end to take out the soil. Four to six such samples were sieved at a time and the grubs were counted. Sampling eight to ten cm depth was found sufficient for first instar grubs. There was no need for sieving for the 2nd 3rd instar grub and up to 30cm depth of soil was necessary at this stage.

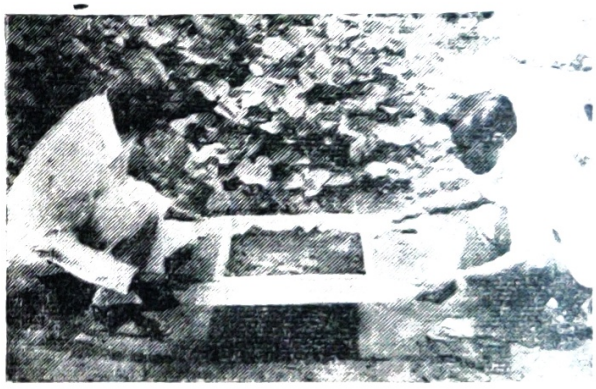


Fig 38. Sieving the soil samples for 1st instar grubs

Prepupa (Fig 40)

Before pupation. the larva burrowed deeper into the soil and formed an earthen cell (Fig. 39). The average prepupal period was 7 days but this was prolonged under adverse condition.

Fig 39. Earthen cells constructed by *H. serrata* larva. Small round ones are egg cells, bigger ones are pupal cells

Fig 40. *H. serrata* prepupa

3.8 Pupa (Fig. 41).

The pupa measured on an average 32 mm long and 15 mm in width. The average pupal period for 43 individuals was 11.8 days under laboratory condition, the minimum and the maximum being 10 and 14 days respectively (Fig. 42). The pupation in the field was observed as early as September (24-9-1971) and pupation was completed before 2nd week of March and the maximum rate of pupation occurred during December and January under Bangalore condition. Pupa did not survive when the earthen cell was damaged. According to Majumdar and teotia (1965) the pupal period was 11.0 days on an average at Ranchi for this species. Pupation usually occurred at depths of 20 to 30 cm. It was at 15 to 20 cm at Ranchi for this species (Majumdar and Teotia, 1965).

Fig. 41. *H. serrata* pupa

The Pupal period for *H. consanguinea*, *H. insularis* and *H. longi-pennis* was 12–16 days, 15-22 days and 22–27 respectively (Avasthy, 1965). *H. consanguinea* pupated at depths of 0.2 to 1.5 m (Kalra and Kulshrestha, 1961). The depth of pupation is not only charcteristic for each species but it also varies according to the temperature for the same species at different places (Ritcher, 1940).

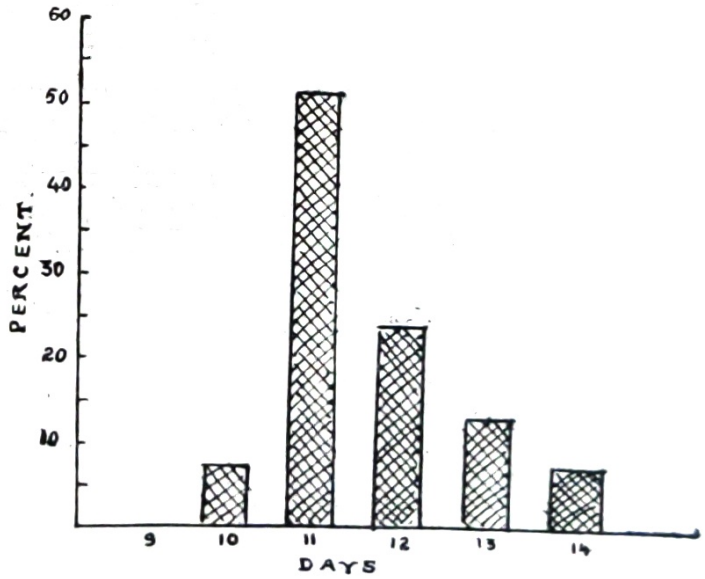


Fig 42. Pupal peroid of *H. serrata*

3.9 Adult (Fig. 11 and 43)

The adult description in given under chapter 2.3

It is difficult to distinguish between the male and the female externally. The portion of 7th and 8th abdominal terga uncovered by

Fig 43. *H. serrata* egg, larva, pupa and adult

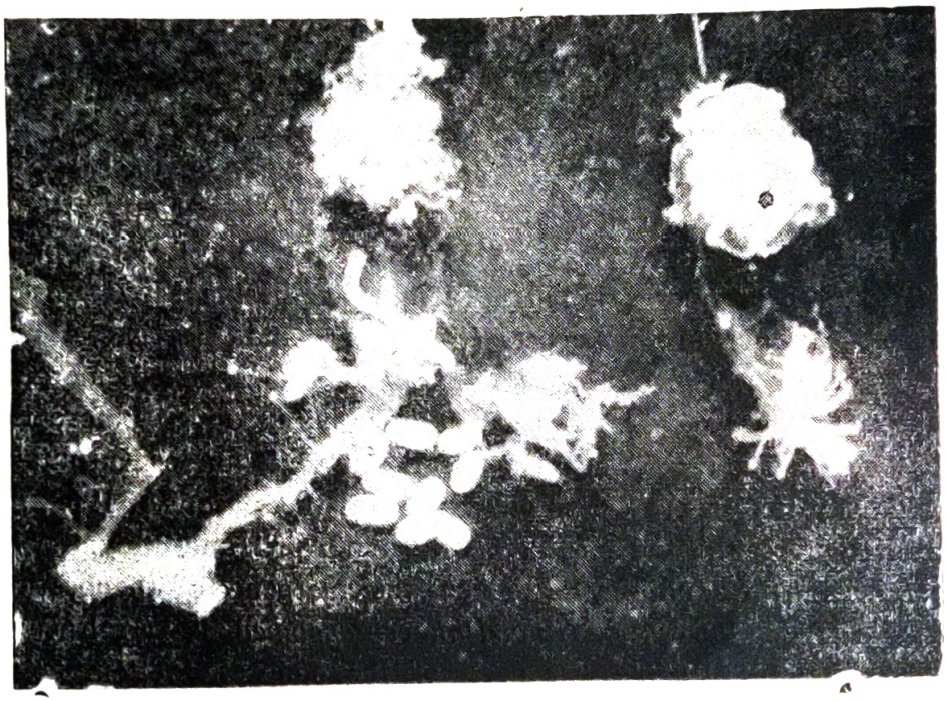


Fig 44. *H. serrata* female reproductive system. Left, fully developed reproductive organ from adults emerged in April. Right reproductive organ not well developed from adult dug out in February

the elytra is suggested as sex distinguishing character (Majumdar and Teotia, 1965), in which the 8th abdominal tergum and a small portion of 7th targum remained uncovered in male whereas in the female a

greater portion of 7th besides eighth is exposed. But this has not been found very reliable. The sex can be distinguished by a more simple method by pressing the abodominal tip between fingers applied laterally in case of fresh specimens, the internal genitalia comes out as soft whitish fleshy mass with the paramera tips visible through the anal end of the male beetles and not in the case of the female. The same method was adopted by Ghosh (1937) to distinguish between the sexes of *Alissonotum* beetles.

The adults remained in the pupal cell until the first rains in April irrespective of pupation time. This condition was designated as hibernation by Majumdar and Teotia (1965). Under the conditions existing here the adults were found not matured sexually until March end (Fig. 44), though they have been formed early in November or December. Cold temperature seems to prevent the development of gonads as was found in case of those adults which were collected from the field in February and kept at 15°C. They showed no sign of development of reproductive organs for over 4 months (up to 15th July). Those that were kept at 30°C in February died within two weeks. Soil temperatures of around 25°C were optimumal for the development of gonads.

3.10 Adult emergence

The adult emergence in North India begins in late May and the beetles are active until August (Majumdar and Teotia, 1965). Under the conditions in Karnataka State, the beetles started emerging from the first week of April and the adult activity stopped before the end of May. The time of heavy emergence of adults under Karnataka conditions varied from place to place and over the seasons of 1969–72, depending upon the time of the first rains in April and May. The first rains in April and May determined the emergence of the beetles. This was true in the case of *Holotrichia consanguinea* also (Kalra and Kulshreshtha, 1961) in other parts of the country. Attempts to make the adult of *H. serrata* emerge out of soil by inundating the soil in January and February, did not succeed under laboratory condition. There was about 5 cm rain on 28th February in 1970 at the Main Research Station, Hebbal, but no adult activity above ground was noticed in spite of their abundance in the soil. Even, if there was 5 to 10 mm rain during April and May, it triggered the emergence of adults. Saturation of atmospheric humidity seems to have more influence on adult emergence in these months than the moisture

content of the soil. Continuous irrigation of the soil or watering the lawns did not induce emergence of all the adults from the soil in the months of April and May, unless at least there was above 50 per cent atmospheric humidity. Stray case of adult emergence did occur in the absence of above conditions but the numbers were negligible compared to the total population.

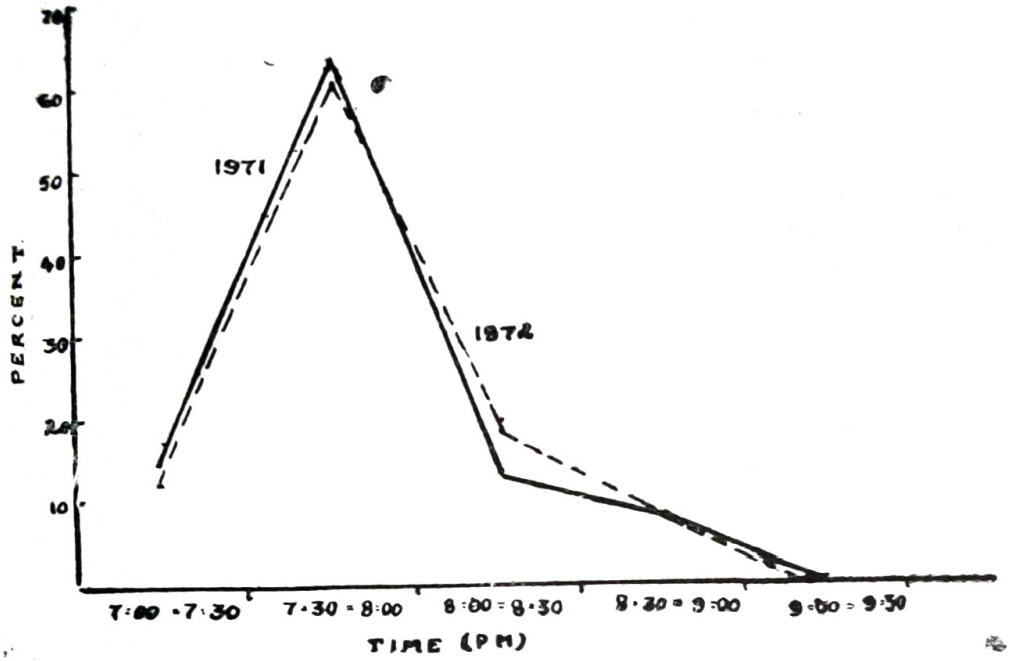


Fig 45. The pattern of adult emergence at half hourly interval

Observations on the emergence of adult *Holotrichia serrata* for four years during 1969–72 showed that more than 90 per cent of adults emerged during the week after the first rains in April (Fig. 46). Some stray emergence was also noticed in November and December but the reproductive system was underdeveloped indicating that they were not capable of laying eggs (Fig. 44). The gonads were fully developed only in the last week of March as was shown by dissecting the female once in every two weeks commencing from December. Adults collected in February from the field and kept at 15°C were found alive till July without development of reproductive organs.

Total failure of rains in April and May prevented adult emergence and consequently the pest disappeared during that year. This situation

occurred at Santemaralli, Chamaraja Nagar Taluk, Mysore district in 1973. There was a heavy incidence of grubs of *H. serrata* in the previous crop over an area of 5 acres of sugarcane field. The adults did not emerge in June when rains occurred. Perhaps, the adults could not wait for long when the gonads were fully developed, if the rains failed in April and May.

The first rain occurred in Bangalore between 10th April to 13th April in all the years under observation except in 1970 when it occurred on 5th April. The emergence of adults from the soil started consistently at 19.15 hours and continued up to 21 hours. Maximum number of adults (about 60 per cent) emerged between 19.30 hours to 20 hours (Fig. 45). The adults emerged on the same day of rains, if it rained before 7 p.m. as it happend on 6th Agril 1970. If it continued to rain even after 7.30 p.m. or if it rained after this time, adults emerged next day at the same hour as it happened during 1969,

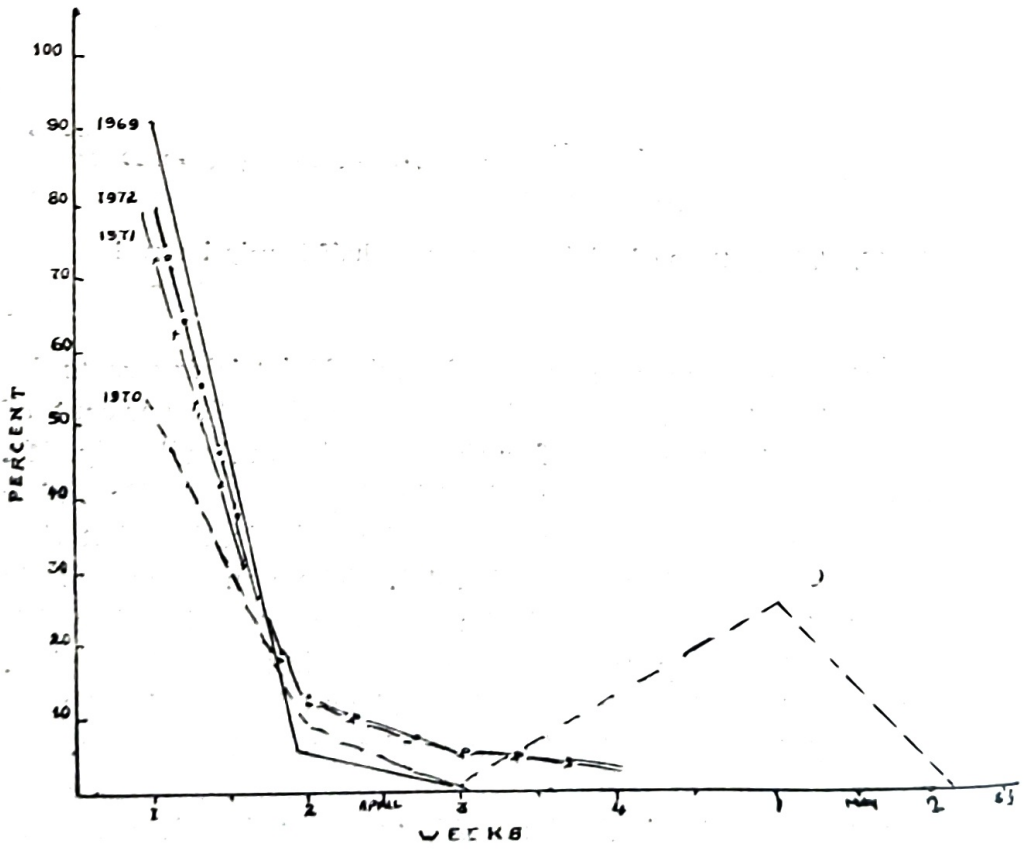


Fig 46. Pattern of adult emergence after the first summer rains

1971 and 1972. Continuous rain throughout the night prevented adult activity.

The observations made in a lawn (Fig. 56) for four years showed that the emergence of adults declined progressively a week after the first rains and there was no emergence after May 15th except in the year 1970 when there was a second rush of emergence after two weeks decline in the emergence (Fig. 46). This was because, the first rains during April 1970 were inadequate and irregular and there was complete break of two weeks which was followed by a heavy rain.

In the light trap experiments at the Main Research Station, Hebbal, the adults were observed to be active up to the first week of June in the year 1973. This was because the summer rains were late, scanty and scattered, and the emergence of adults was also irregular.

The adults were active throughout the night but majority of them migrated back to the soil before 10 p.m., unless they found suitable host plant to feed when they spent more time outside the soil during night.

The abundance of adults and the future problem of the root grub during a particular year could be judged by the presence

Fig. 47. *H. serrata* adult emergence holes

of emergence holes, about 10–12 mm in diameter (Fig 47). The emergence holes left by the emerging adult from the soil were round and clear, sufficient to insert the little finger. These holes were more conspicuous in clayey loam soil. The holes remained intact for about a week if there were no subsequent rains. The adult emergence holes were the first clue for the presence of this pest and one or two holes per square foot was the sure indication for heavy infestation

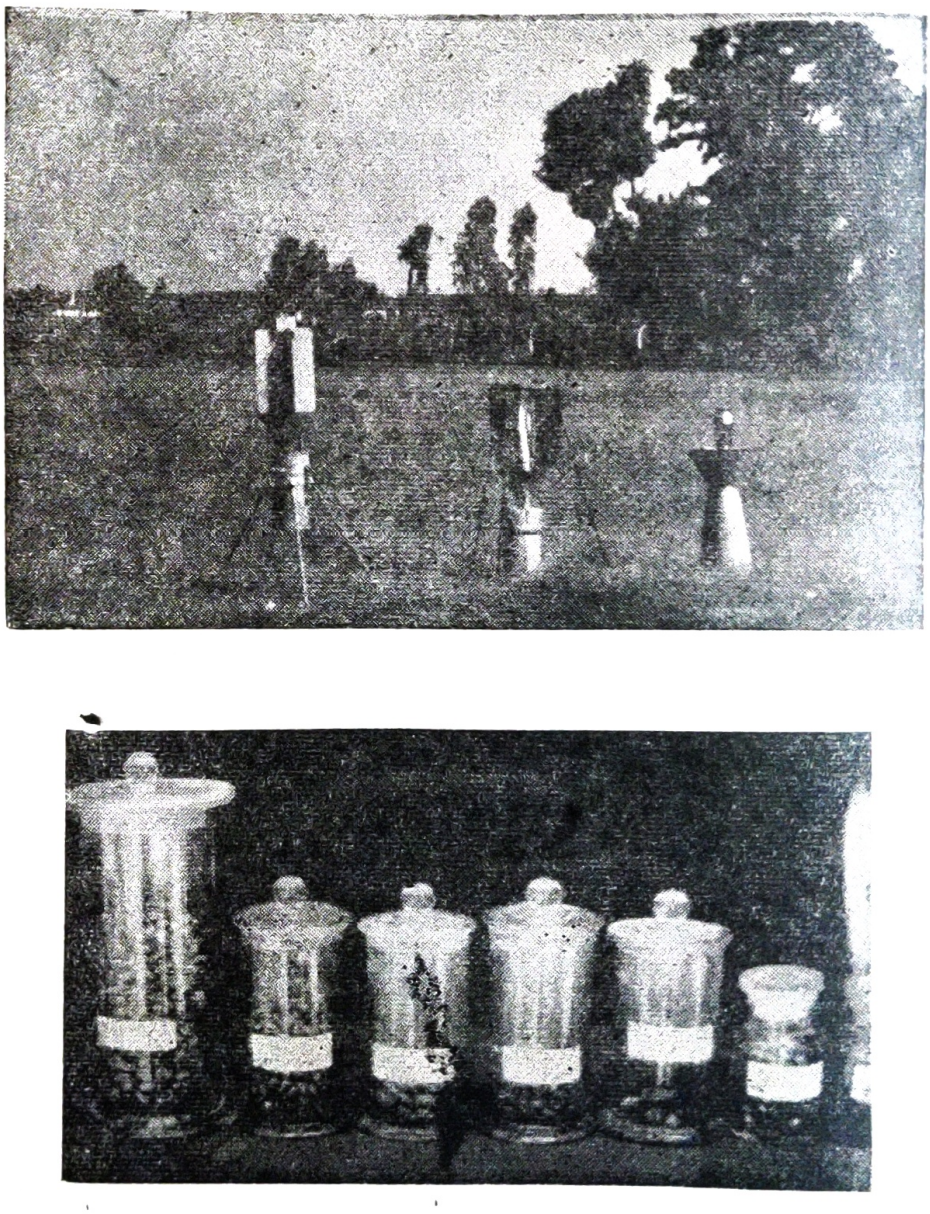


Fig 48. Top, lighttraps; left, black light; centre, fluorescent light; right petromax light. Bottom, six species of beetles traped in one night from black light. Second from right, *H. serrata*.

necessitating control measures. Another indication for the early detection of this pest was the presence of excreta underneath the adult host plant and characteristic defoliation of the host plants (Fig. 54) specially neem and *Acacia.*

After emerging from the ground, the beetle flew straight towards a nearby tree or shrub. Feeding usually took place after copulation.

An attempt was made to find out if the female beetles would fly on successive night or not. In 1972, 90 beetles, 56 females and 34 males were marked with white enamel paint on the pygidium and liberated in the lawn. On the subsequent 3 evenings, seven, eleven and five female beetles were recovered, indicating that some female beetles will reappear above ground on subsequent nights after going back to the soil. Under laboratory condition one female beetle was recaptured 4 times. On the other hand majority of males appeared daily after the first emergence. Latter in the season, the female dominated.

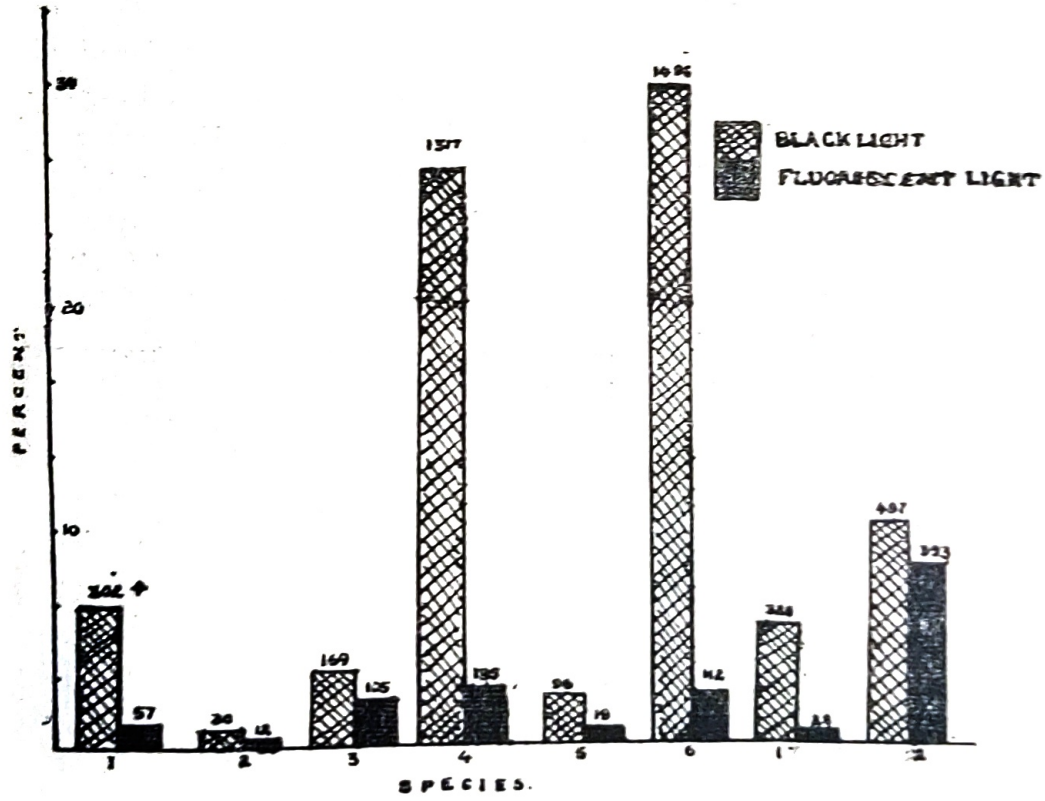


Fig. 49. Comparative efficacy of black light and fluorescent light for 8 species of chafers (April-June 1972)

Three sources of light, the black light, fluorescent light and petromax light (Fig. 48) that were tried to attract the adult at the time of emergence did not trap all the emerged beetles. Among the 3 source of light, the petromax light was least attractive and black light was comparatively better than the fluorescent light. However, in the case of black light trap most of the beetles that came near the light source fell on the ground. In one night as many as 186 beetles were collected around 15–20 m radious on the ground compared to 7 adults captured in the black light trap. Though the beetles were attracted to light they did not dash towards the source of light. This finding has limited the scope of using light trap as a means of control for *H. serrata* unless the inhibiting factors in the source of light are removed.

3–11 Host Plant

Adults were observed to feed on the following host plants. *Swietenia mahagoni* Linn. *Azadirachta indica* Ajuss (Hoskote, Bangalore district and Hospet, Bellary district) : *Syzigium jambolanum* DC, (Doddakuppe, Bangalore district); *Musa sapientum* Linn., (Vasantanagar, Bangalore); *Rosa* species (Bangalore); *Psidium guajava* Linn., *Achras sapota* Linn., *Vitis vinifera* Linn., (Doddakuppe, Bangalore district); *Canna indica* Linn., (Hebbal, Bangalore); *Moringa pterygosperma* Gaertn., *Prunus malus* L; *Prunus persica* Benth and HK (Jayanagar, Bangalore); *Ficus religiosa* Linn., (Melur, Kolar); *Cassia fistula* Linn., (Devangi, Shimoga district); *Pithecolobium dulce* Benth (Hospet, Bellary district), *Acacia arabica* (Ugarkhurd) ; *Morus alba* L. (Bangalore district). The adults preferred neem and *Acacia* to other hosts when they occurred together. The damage was very severe on grapevine (Fig. 50) at Doddakuppe and Melur in 1972 when the shoots were severed along with the inflorescence. A severe defoliation *Morus alba* by *H. serrata* was

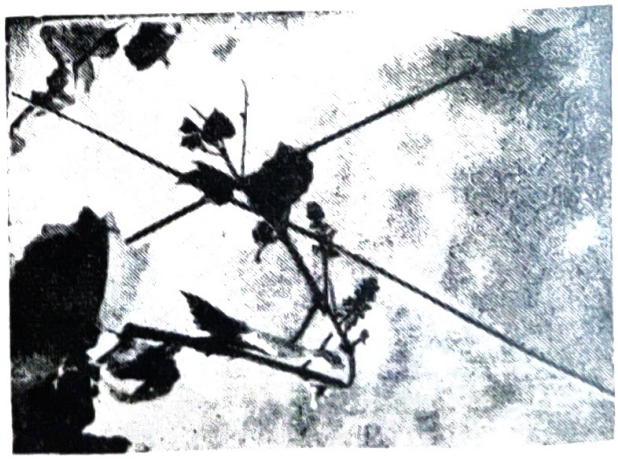


Fig 50. Grapevine damaged by *H. serrata* adult

reported by the Assistant Director of Central Sericulture Research and Training Institute, Devanahalli Farm, Lalgundanahalli (Bangalore district) during April-May 1976. The adults preferred variety S.36 to variety Kanva, local, and Kosan mulberry.

3.12 Mating, preoviposition period and longevity

The proportion of males was higher in the initial stages but later on more females emerged and in a week's time the females predominated. Similar observations were made by Kalra and Kulshrestha (1961) in *Lachnosterna consanguinea* (*H. consanguinea*).

Mating: Mating usually started immediately after emergence, on the host plant. Copulation lasted for 4 to 5 minutes. The abdominal tip of the two opposed each other during copulation. A female mated only once, whereas the male was capable of mating with more than one female. Krishnaswami *et al.* (1963) found this species first settling on the host tree and then copulating. Similar observations were made by Majundar and Teotia (1965).

The adults migrated back to the soil before dawn. If suitable host was available they continued to feed till the early hours. Otherwise they got back to the soil early. Krishnaswami *et al.* (1963) noted the beetle migrating back to the soil between 3 and 3.30 a.m.

Preoviposition period: The preoviposition period varied from four weeks to seven months. Majundar and Teotia (1965) have recorded the preoviposition period for this species as, from 169 to 224 days if the winter did not intervene.

The period between mating and oviposition was five days in *Holotrichia consanguinea* (Kalra and Kulashrestha, 1961) and 4 to 6 days for *Holotrichia insularis* (Srivastava and Khan, 1963). *H. serrata* oviposited the day after copulation.

Longevity: Sixty two field collected beetles lived an averaged 15.0 days after emergence from the soil. The maximum was 23 days. Thirty two laboratory reared beetles, lived an average of 15.5 days, the maximum being 21 days. However when pupal cells containing the adults were subjected to 15°C the adults lived for over five months. This cannot be taken as the normal longevity of adult. There was no difference in longevity between male and female.

The longevity of male and female of *H. consanguinea*, *H. insularis* and *H. longipennis* is 80–93 days, 28–41 days, and 28–56 days respectively (Avasthi, 1965).

Total life cycle: The total life cycle from egg to adult for *Holotrichia serrata* occupied an average of 177.9 days with one generation per year. At Ranchi it was 170.6 days (Majumdar and Teotia, 1965). The totally life cycle for *H. consanguinea*, *H. insularis* and *H. longipennis* was 76 to 96 days, 77 to 112 days and 291 to 339 days respectively (Avasthy, 1965).

3.13 Natural enemies

The parasites encountered during the extensive survey of the pest in the State on the grub include a fungal parasite, *Beauveria brongniartii* (Sacc) (Fig. 51), recorded for the first time in India,

Fig. 51. *H. serrata* larva killed by fungus *Beauveria brongnierti*

and a scoliid parasite (Fig. 52). The fungus was viable in the soil for more than 3 seasons under Bangalore condition and attacked all the stages of the pest. Up to 30 per cent scoliid parasitization was observed on *H. niligiria* in a coffee estate during September-

October 1975. The other natural enemies were the crow (*Corvus splendens*) and the Indian Mynah (*Acridotheres tristis*) which took every opportunity to locate the grubs and devour them. They were found to be very effective in reducing the population of grubs, particularly at the time of tillage. Similar observations were made by Avasthy (1965) and Kalra and Kulshrestha (1961). A carabid predator. *Pheropsophus sobrinus* was found feeding both on adults and grubs during night time.

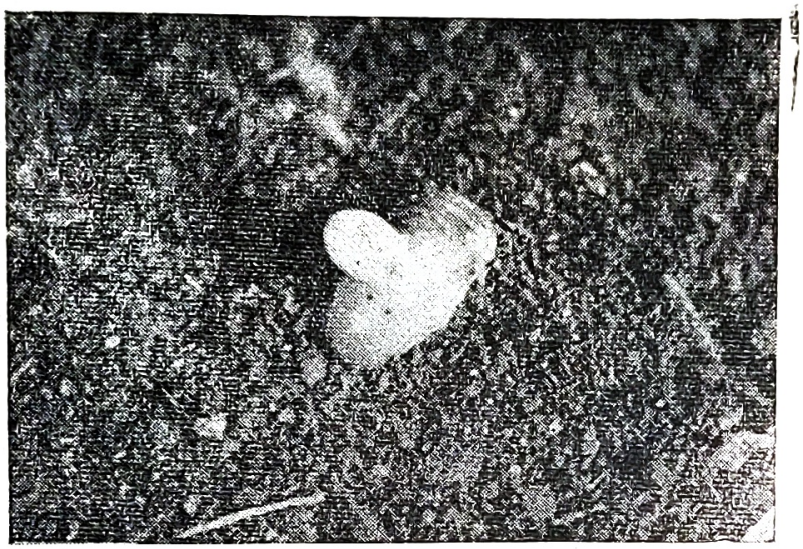


Fig. 52. *H. serrata* larva parasitised by *Scolia* species

Fletcher (1921) found the Indian Hoopoe (*Upupa epopa* indica) effectively controlling the root grubs, as because its long bill could penetrate the soil and extract root grubs. The common Indian toad (*Bufo melanostictus*) and a carabid beetle (*Anthia sexguttata*) were reported to feed on the adults of *Holotrichia* spp. (Kalra and Kulshreshta, 1963). These predators commonly congregated near the light source after the rains in summer when the adults emerged but they did not feed on the adult *H. serrata*, perhaps because the adults were too big to catch and eat.

The white grubs, once very serious pest of sugarcane in Puerto Rico disappeared after the giant toad (*Bufo marinus* L.) was introduced and established in the plantations (Box, 1953). Because of the extensive use of insecticide the toad population decreased and consequently the white grubs are once again increasing according to Box (1953). Rangaswamy and ChannaBasavanna (1974) have

reported from Karnataka that 23 per cent of the total food of *Bufo melanostictus* Schneider constituted scarabaeids including adults and grubs.

The scoliids (*Campsomeris colloris* F. and *Scolia aureipennis* Lep.) have been recorded as parasitising the grubs at Dalmianagar in Bihar (Gupta and Avasthy, 1960). Bulansher, U. P. and at Coimbatore (Avasthy, 1964). Several scoliid parasites are collected from Bangalore (Channa Basavanna, 1954). The green muscardine fungus *Metarrhizium anisopliae* Match, and white muscardine fungus *Beauveria bassiana*, have been seen to kill the adults in 4 to 6 days (Gupta and Avasthy, 1960; Rao and Vijayalakshmi, 1959) in this country and the same have been noticed in stray cases, during the course of this study here.

4. Control

During the course of this study no single method of control was found to be a solution for the root grub problems in the State. Widey distributed species like *Holotrichia serrata* requiring one year to complete the life cycle, may very in the timings of different stages of their life cycle from place to place depending upon the season and rainfall. The problem of control or combative measures against white grubs is therefore a local problem and successful control depends in a large measure upon the knowledge of not only the biology of different species but also the biology of a given species under local conditions. Similar observations have been made by Reinhard (1944). The various control measures adopted during the course of this study have clearly indicated that any method must be applied at the right stage of the insect to be effective. The control measures discussed hereunder are aimed at combating any root grub problem, provided the behaviour and biology of the given species is known. An integrated approach to the problem of the root grubs seems to be the practical solution in checking their menace. Long and Hensley (1972) are also of the same opinion. Keeping this in view several methods were tried and they are discussed below.

4.1 Mechanical method

(a) Adult collection: Since the adults emerge during the particular hours between 19.15 and 21 hours after the first rains in April

under Bangalore condition and are attracted to certain host plant like *Azadirachta indica* (Fig. 53) *Swietenia mahagoni* (Fig. 54) and *Acacia arabica* (Fig. 55) catching and killing the adults was found to be a

Fig 53. *Azadirachta indica ;* defoliated by *H. serrata*

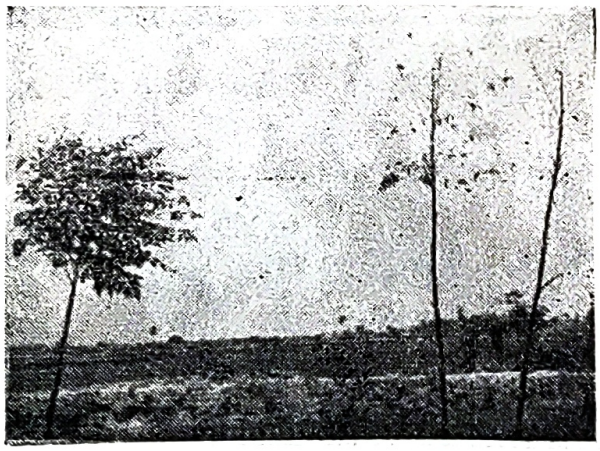


Fig 54. *Swietenia mahagani ;* defoliated by *H. serrata*

satisfactory measure as a result of four years observations in one of the lawns in Bangalore (Fig.56) during 1969–72. There was a marked reduction of adult beetles by 80.1 per cent, 84.8 per cent, and 85.1 per cent during 1970, 1971 and 1972 respectively, compared to 1969, the year of first collection. A small percentage of adults (about 15

per cent) continued to occur during 1971 and 1972, as there was scope for the adult to migrate from the neighbouring compound after 21·00 hours when collection was stopped every day. The lawn was free from grub damage as a result of adult catching and killing. This method may not be effective in controlling the pest in a larger area

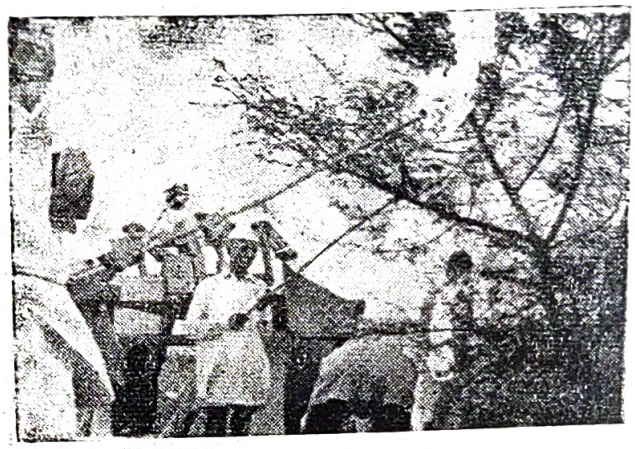


Fig 55. *Acaci arabica* defoliated by *H. serrata* adult

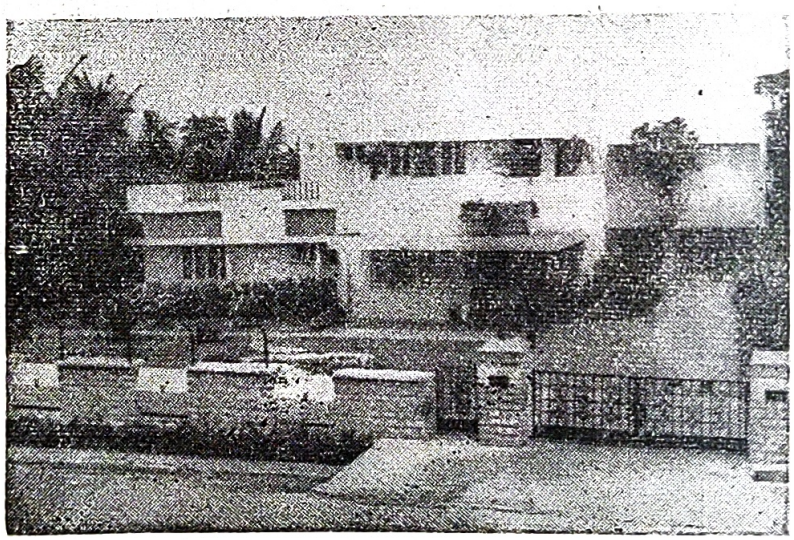


Fig 56. Lawn where most of the preliminary observations were made on *H. serrata*

under standing plants, unless it is done by all the people concerned collectively. Davis (1916) is also of the same opinion. If collection is done conscientiously this can be one of the cheapest and best methods because 70 per cent of adults emerge within the first 3 days

after the first rain, and more than 90 per cent emerge in the first ten days. Also all the emergence of the day will be over within two hours in the early night (Fig. 46). One day two people collected 1,922 beetles with the help of a petromax light from a lawn 6,000 sq ft Kalra and Kulshrestha (1961) reported collection of 3,000 beetles by 2 men in two hours. Sripathi Rao (1967) found adult collection useful in reducing the population in Malayan rubber plantation. Leefmans (1915) got one third reduction on 78 acre plot by employing 25 men to go round once at dusk till one hour after night fall. Veeresh (1974) reported, that the Ugar sugar factory authorities, Karnataka, collected 2.4 million beetles in one week

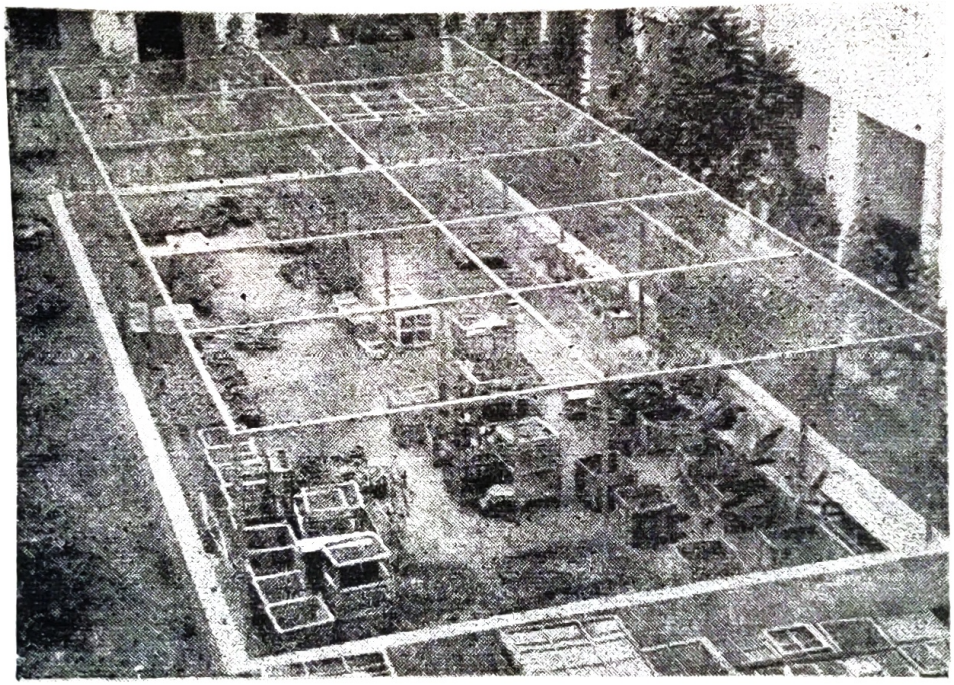


Fig 57. Insectory where most of the laboratory studies were made on Melolonthine beetles

employing 200–250 people every day in their 1,750 acres of sugarcane field using locally made torches (Fig. 58). Raodeo and Despande (1974) reported to have collected and killed 8.86 million adult in one season.

Several cultivators in the districts of Kolar, Bangalore and Tumkur have successfully controlled this pest by adult collection. Mr. Venkatappa, A.D., a progressive cultivator from Sidlaghatta–Kolar district collected 21 bucketful (12 litres capacity) of beetles in 3

nights in his 40 acres land (personal communication). He cut the branches of Neem trees and planted (Fig. 59) before dusk after the first rains in April 1973 to attract the adults every day.

During 1976 April the entire village of Mahadeswarapur (Pandavapura Taluk, Karnataka) was mobilised by the efforts of the personnels of the Department of Agricultnre and the University of Agricultural Sciences extension wing, to collect the adults in an area of over 400 acres, which was badly damaged by the grubs in the previous season. More than a hundred thousand beetles were collected on the first day by over 100 people using petromax light and local torches as a source of light. Freshly cut neem branches were planted at convenient places to attract the emerging beetles (Fig. 59) and

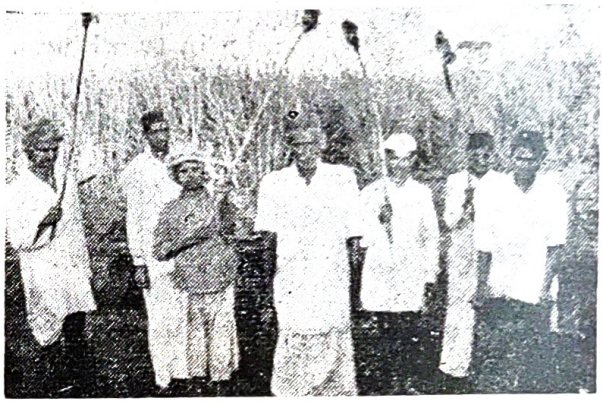
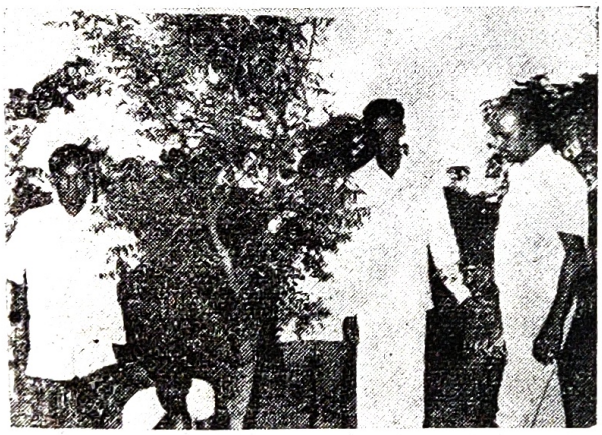


Fig 58. Local torches used as a source of light at the time of adult collected



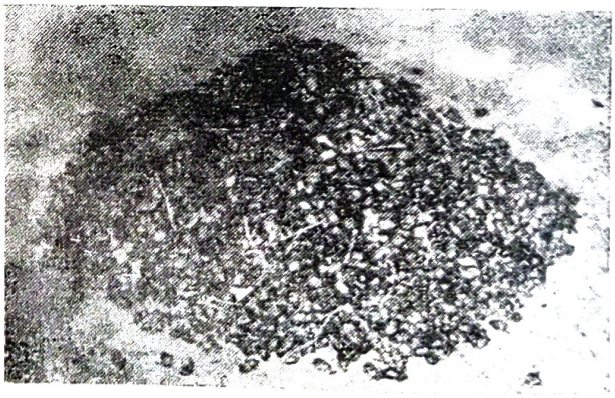


Fig 59. Top – a branch of neem tree *Azadirachta indica* is being planted as a source of attraction to adult *H. serrata* Bottom, *H. serrata* adult collection heaped before burning

the collected beetles were heaped and burnt. Similar reports are available from Uttar Pradesh (Gupta, 1973).

Fig 60. Grub infested fields cleared from roots and rubbish and heaped to attract the grubs

Shivarudrappa and brothers (personnel communication) of Tondevadi (Mysore district) used smoke, emitted by burning paddy straw, to dislodge the beetles sitting on neem trees and were collected. The resultant fallen beetles and burnt. They found this method more effective than spraying the host plants with insecticides to kill the adults.

Adult collection as a means of control to be effective must be done immediately after the first rain in April–May. Even if it is delayed by one day the first day's emergence is just sufficient to produce enough grubs capable of doing economic damage. This method will not be effective if the summer rain is weak and spread over a long period.

(b) Larval collection: The larval collection by digging and hand-picking was not found feasible as a means of control. In an area of 20 acres of coffee plantation at Koodanahalli Estate (Hassan district) an attempt was made to collect the grubs while digging. For every hundred grubs collected, one Rupee was paid to the labourers. About 70,000 grubs were collected in a week during September 1971. However there were enough grubs left to cause economic damage to two year old plants. The labourers in their anxiety to collect more grubs did not bother to collect all the grubs present.

(c) Light trap : Among the three sources of light tested (Fig. 48) in the light traps, against *H. serrata* the black light and the fluorescent light showed some attraction to the adults. About 85 per cent of the adults attracted to light fell on the illuminated ground, 2–3 m around the source of light, where they returned to the soil. Sripathi Rao (1967) found similar situation in the case of *Psilopholis vestia* and *Lepidiota stigma* which though attracted to light, fell on the illuminated ground.

About two hundred thousand *Holotrichia consanguinea* have been trapped by Gupta (1958) at Dalmianagar in one year from a 2 ft. fluorescent tube light. Light traps tested against 21 species of *Lachnosterna* at Iowa, U.S.A., was found ineffective in trapping the beetles (Travis, 1953). Among the six melolonthine beetle captured in the light trap only for *Schizonycha ruficollis* the light trap was found to be effective. The black light trap captured 1,317 beetles compared to 302, 30, 169, and 96 for *H. serrata H. reynaudi*, *Apogonia ferrugenia* and *Autoserica* species respectively between April 14th and 31st May, 1972 (Fig. 49). The rutellinid beetle, *Adoretus bicolor*

Brenske was found to show equal preference for both Black light and fluorescent light (Veeresh, 1974).

4.2 Cultural method

(*a*) *Cleaning the field and heaping plant refuse:* Clearing the field of all weeds and plants and heaping them 2 to 3 m apart (Fig. 60) helped to concentrate the grub to a limited area, rather than leaving the field fallow during the active grub period to reduce the grub population. The experiment conducted at Hoskote kodi showed that in 2 to 4 weeks time most of the grubs, from the cleared area, migrated to the plant refuse. Those which were under heaps were found nearer the surface, which helped to kill the grubs easily either by mechanical means or by chemical means. This method would help to reduce the population to a minimum to take up any cultivation later instead of leaving the field fallow as suggested by some workers (Avasthy, 1967) during June–September months as is being done now in some places in the endemic areas around Bangalore.

(b) Trap crop: An experiment conducted at the Tobacco Research Station, Nippani, Belgaum district, it was found that onion

Fig 61. Grub infested, field puddled and paddy being planted

sown at 2 m apart, after the first rains in summer attracted more grubs (*H. serrata*) towards their roots compared to millets. This method was found very effective in preventing the grub damage to later planted tobacco, provided all the grubs attracted by the onion were collected and killed.

(*c*) *Flooding and puddling:* Puddling and paddy cultivation gave cent per cent control (Fig. 61). Puddling and leaving the land to dry did not give cent per cent control as was shown by the observation made at Nandi cross, Chickballapur (Bangalore district). Only such of the grubs which were mechanically injured died and the others remained in earthen cells until favourable conditions arrived. Samples taken after four weeks of puddling and leaving fallow,

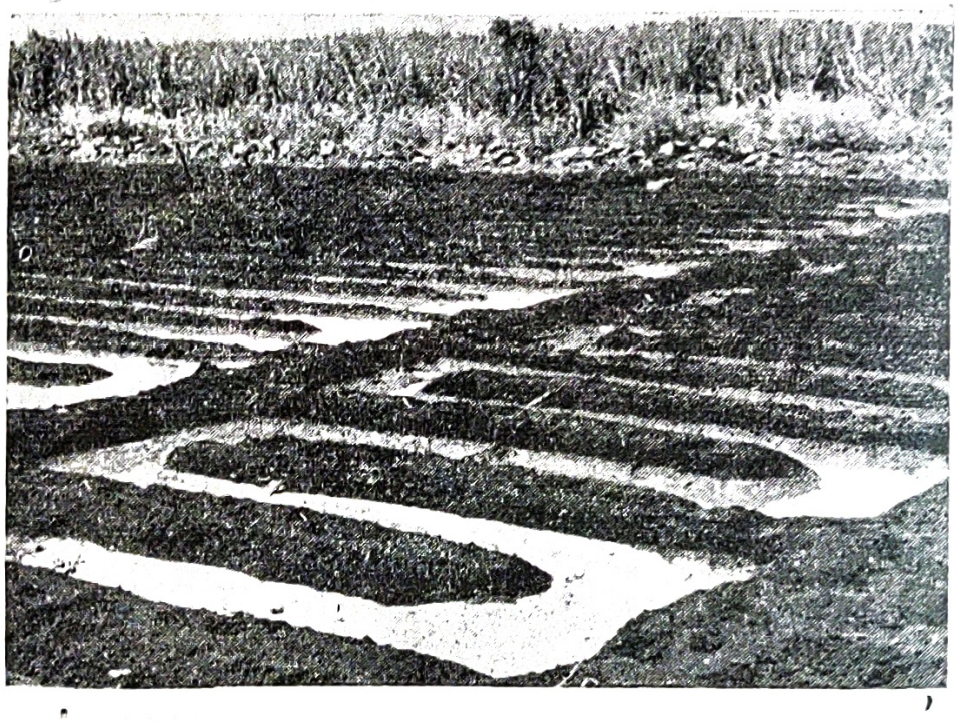


Fig 62. Sugarcane field flooded to force out the grubs from the soil

showed several grups still healthy lying in earthen cells during June–July. Similar observation was made by Gupta and Avasthy (1957) at Dalmianagar, Bihar where only the grubs which were on the top died and the rest migrated up to 40 cm deep.

Puddling and paddy cultivtion gave relief during the year of operation and in the coming season there was a chance of getting an infestation unless, either the field was under standing paddy crop, or

all the neighbouring farmers took up paddy cultivatton simultaneously in one season.

Flooding the field (Fig. 62) for 4 to 6 hours forced the grubs out of the soil but as water receeded, they went back once again. Flooding was not found practicable as a means of control for the grubs, unless the water was made to stand for over six days.

(*d*) *Resistant crops:* Pot culture experiments showed that sunflower, *Helianthus annuus*, (Fig. 32) with stood the attack of the root grubs provided enough moisture was present, and the tap root was not damaged. Similar observations have been made by Philip, and Chamberlin (1938) and they designated sunflower a 'very resistant plant'. Davis (1916) suggested sunflower as an alternate crop to withstand the attack of grubs. Sugarcane variety Co–935 and B–O–3 was reported to withstand the attack of larva better than other varieties in Bihar and Bulanshar U.P. (Avasthy, 1967 ; Agarwal and Siddique, 1964).

(*e*) *Ploughing*: Repeated ploughing reduced the grubs by 28.24 per cent in the first ploughing to 89.60 per cent in the 6th ploughing. There were 9.2 grubs per sq m before the first ploughing and

Fig 63. Ploughing as a method of control. Birds picking the grubs during tillage

the same were reduced to 1.2 grubs per sq m after the 6th ploughing. There were several factors contributing for the reduction of the grups in each ploughing. The main factors responsible

for the reduction were the birds like Crows (*Corvus splendens* V) and Mynahs, (*Acridotheres tristis* (W) (Fig. 63) who followed the plough and plucked every exposed grub. Some reduction was due to mechanical injury from the plough and trampling by the bullocks. Yadava *et al.* (1973) have made similar observations. D' Abreu (1919) has found as many as 101 grubs in a bird stomach (*Inocotis papillosus*).

4.3. Biological method of control

a) Microbial control: Laboratory studies made on the fungus, *Beauveria brongniartii* (Sacc.) Petch, [Syn. *B. tenella* (Del.)] has shown promise of using it to bring down the population of the pest. This was reported from India for the first time (Ranganathaiah *et al.*, 1972). All the stages of the insect were susceptible to the attack of this fungus. The only limitation, as with any other fungus, was that this fungus also required high humidity and temperature for quick growth. The grubs stopped feeding after two weeks of infestation and in the third week the fungal growth was visible externally. Later the infested grub became a white mass (Fig. 51).

Under field condition the grubs were found to acquire the fungus during August–September when there was intermittent rains and sunshine under Bangalore condition. In one of the survey made for the grubs in coffee estates, all the samples collected in one estate near Sakalespur (Hassan district) were found infested with this fungus during September 1975. Similar observation was made in one of the Areca gardens at Bhirumbe–North Canara district during September 1971. The fungus was found viable for several years in the soil. It was one of the major controlling agency in nature.

Nirula *et al.* (1952) and Avasthy (1967) have reported *Metarrhizium anisopliae* (Metchnikoff) the green muscardine as controlling grubs in India. During September 1975 a small percentage of grubs from a coffee estate were found infested with this fungus.

b) *Pigs as predators*: In addition to the birds preying on grubs during tillage operations, pigs were found to feed on the pest (Fig. 64). Thirty seven pigs grazed 3 days in one of the grub infested plots during August 1971 and brought the infestation to a non-pest level. There was a significant difference in the yield of

sorghum between the grazed and ungrazed plots. Forbes (1916) reports the destruction of 99 per cent of grubs in a badly infested ten acre cornfield in which 100 pigs and 8 cows pastured for 27

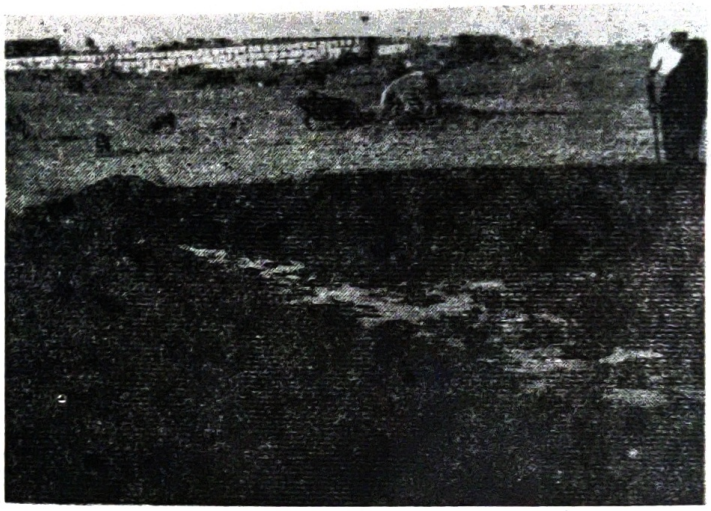


Fig 64. Pigs grazing on grubs

days. This method of control may not be suitable under cropped conditions when the grubs are very small. However, if late planting is desired in an infested area, pasturing with pigs will be quite useful.

4.4 Chemical method

The time of application and method of application is very important for any chemical to be effective against grubs. This was indicated by several experiments conducted during the course of this study (Fig. 65).

In the two field experiment, out of 5 chemicals tried, except heptachlor dust and EC at 1.81 kg a.i. per acre and disulphoton 5G, 0.75 kg a.i. per acre, the rest have all given significant control at a 5 per cent level over the check. Phorate 10 G at 1.00 kg a.i. per acre, carbofuran 5 G at 0.30 kg a.i. per acre and Pyridyl phosphate (dursban) 20 EC at 0.48 kg a.i. per acre have not only proved superior to control but also to chlordane 75 EC at 2.72 kg a.i. per acre, disulphoton 5 G at 0.75 kg a.i. per acre, and heptachlor at 1.81 kg a.i. per acre. Carbofuran was slightly superior to phorate

and pyridyl phosphate (dursban). The chlorinated hydrocarbons, being slow in their action in the soil, against grubs, were not found effective when the observation was taken 24 hr after treatment.

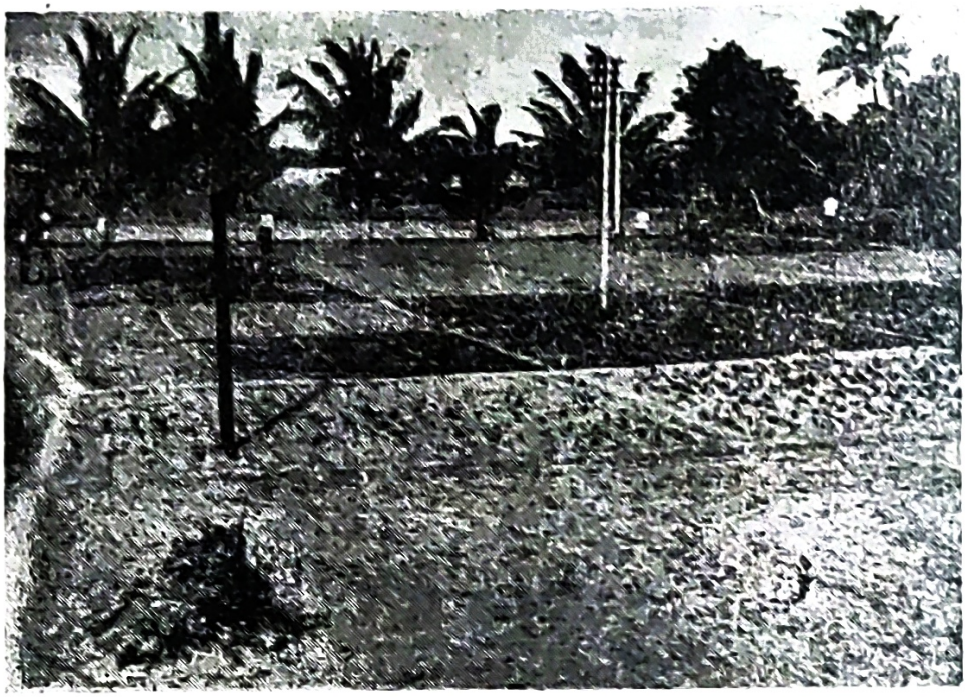


Fig 65. Insecticidal trial showing contrast between treated and untreated

Phorate 10 G at lower dosages of 0.56 kg to 0.79 kg a.i. per acre uniformly applied to the soil before sowing when the grubs were in the first instar, has given the same effect as that of 1.00 kg a.i. of phorate per acre as reported earlier (Veeresh, 1972). Dosages twice those used in this experiment, did not prove satisfactory under planted conditions, when the grubs were sufficiently grown up particularly in sugarcane field and ratoon sorghum field. To get maximum benefit from insecticides and to obtain good control of grubs, the insecticides must be applied before sowing and three to four weeks after the first summer rains, when the eggs and first instar grubs will be confined to about 5 cm depth. The pesticides should be incorporated uniformly in the infested field when there is enough moisture. Timing of the application of insecticides, particularly the carbamates and phosphatic groups which loose their toxicity quickly in the soil, should be synchronised with the emergence of adults which always occurs after the first summer rains. The application of chemicals too early or too late than the times

specified here would result in not getting satisfactory control. None of the chemicals found effective against grubs under unirrigated conditions and in dry lands, (Veeresh, 1976; Veeresh *et al.*, 1976), Best results were obtained only when the plots were irrigated immediatly after treatment.

The application of insecticide synchronously with oviposition has been found effective in controlling *H. consanguinea* in Bihar (Gupta and Avasthy, 1957: Kalra and Kulshrestha, 1961; David and Kalra, 1964). Prasad and Thakur (1959) found that application of heavy doses of contact insecticides like aldrin, dieldrin, endrin, DDT and BHC around the base of sugarcane clumps in September were not satisfactory. Similarly, Kalra and Kulshrestha (1961) found the insecticides ineffective when applied in August and September. It has been shown by Tashrio and Fiori (1969) that chloradane and dieldrin at initially recommended doses of 24.4 kg and 5·6 kg respectively per hectare against European chafer could be reduced to 4.5 kg 1.1 kg. if applied when the pest was at the 1st instar instead of 3rd instar.

5. Summary

The present investigations on the root grubs and their control in Karnataka include studies on the melolonthine beetles (Coleoptera, Scarabaeidae) of Karnataka with special reference to the bionomics and control of *Holotrichia serrata* Fabricius.

1. *Faunistic study*: The faunistic study of the melolonthine beetles occurring in Karnataka revealed fourteen species coming under five genera. Ten are newly recorded from Karnataka. Four out of fourteen species are major pests in the different agroclimatic conditions of the State. *Holotrichia serrata* though found all over the state is more severe in the district of Mysore, Bangalore. Kolar, Tumkur, Raichur, Belgaum and Bellary and is a serious pest of vegetables, oil seeds, pulses, cereals, millets and sugarcane *Holotrichia nilgiria* Arrow and *H. sculpticollis* Blanchard is confined to the entire coffee growing area of the State and they are serious pests on coffee. *Leucopholis lepidophora* Blanchard and *Leucopholis coneophora* Burmeister are found in the areca growing areas of the State including North Kanara, Shimoga, Chickmagalore and South Kanara districts. The others including *Autoserica atratula*

Dalla Torre; *Autoserica nilgirina* Frey; *Apogonia ferrugenia* Fabricius; *Holotrichia rufoflava* Brenske; *H. excisa* Moser; *H. reynaudi* Blanchard; *H. heterotincta* Frey, *H. rustica* Burmeister: *Schizonycha ruficollis* Fabricius are of minor importance and found all over the State.

Keys to the adults of the genera of melolonthine beetles of Karnataka and of species of *Holotrichia*, found during this study, are provided. Illustrations of adults along with the male genetalia are also given.

2. Bionomics

A detailed study of the bionomics of *Holotrichia serrata* has brought out several aspects which are directly useful in evolving control measures.

Adult emergence began after the first rains in April under Bangalore conditions and more than 90 per cent of adults emerged during the week after the first rain.

Emergence of adults was confined to the early evening hours between 19.00 and 21.00 hr. Mating took place immediately after the emergence. The beetles migrated back to the soil before dawn after mating and feeding.

A female laid on an average 26 eggs individually in earthen cells at depths of 8 to 16 cm starting from the next day after emergence. Under field conditions, egg laying was mostly concentrated around 5 m distance from the adult host plant. Incubation varied from 10 to 12 days. Eggs were viable for over 5 weeks at 15°C.

The 3 larval instars took an average 30.2, 30.8. and 102.9 days respectively. The third instar larva is described and the larval structures of toxonomic importance, namely the labrum, epipharynx, clypeus, cranium, mandibles, maxilla, and raster are described in detail.

The first instar larvae developed normally on the organic matter. The second and third stage required live roots for normal development. The absence of live roots at least in the third instar retarded pupal formation.

There was no vertical movement during the day but grubs moved laterally up to 30 cm a day. Under saturated conditions grubs

came to the surface and did not survive beyond 7 days under complete saturation. Under drought conditions, grubs of any stage went deeper, up to 40 cm, and became quiescent. First instar was found to lie in the earthen cell up to 110 days after hatching, under drought conditions and completed further development normally under favourable conditions.

There was no crop completely resistant to the attack of the grubs. However a weed, *Galinosoga parviflora* Cav., and sunflower *Helianthus annuus* Linn, have been found to withstand the attack of the grubs.

The average pupal period was 11.8 days under laboratory condition. The pupation in the field started as early as September and all the larvae pupated before 2nd week of March. The maximum rate of pupation occurred during the month of December and January under Bangalore conditions. Pupation usually occurred at depths of 20 to 30 cm depending upon the soil.

Though the adults were formed during November and December the beetles did not attain sexual maturity until the end of March and did not emerge until the first rains in April or May. The average longevity of an adult after emergence was 15.5 days, the maximum being 23 days. The adult survived for more than 5 months at 15°C in pupal cell.

There was no difference in the facundity between the beetle that fed and those that did not. The adults preferred *Azadirachta indica* Ajess and *Acacia arabica* L. to the rest of the host plants recorded. The total life cycle on an average was 177.9 days and there was only one life cycle per year.

The natural enemies recorded on the insect during the course of this study include a scoliid parasite, carabid predator *Pherophus soprinus* and a fungus *Beauveria brongniartii* (Sacc.) Petch. This fungus is being recorded for the first time in India. All the stages of the pest except egg were susceptible to the attack of the pathogen.

3. Control

1) Since the adult emergence was Synchronous the collection and killing of adults was found to be one of the most effective means of controlling the pest.

2) Light attracted the adults but the light traps were not a useful means of control.

3) Cleaning the infested field free from plants along with roots and heaping the same 3 m part after the first rains helped to concentrate the grubs in the limited areas under the heaps in 4 to 6 weeks. The killing of the grubs either by mechanical means or by chemical means was then more effective.

4) Paddy cultivation in infested field during June–September gave cent per cent control of grubs compared to Flooding, Puddling once and leaving the field fallow were not effective.

5) Repeated ploughing once in 3 days, four to six times after the first rains would reduce the grub population to a non-injury level.

6) Laboratory studies made on the fungus *Beauveria brongniartii* showed that the pathogen could control the grubs.

7) Field studies have shown that 30 to 40 pigs allowed to graze in infested field for 2 to 3 days, could bring down the grub population to an uneconomical level.

8) In the chemical control, the time of application and the method of application decides the effectiveness of the chemical. Among the six insecticides tested in field experiments, phorate 10 G at 1,00 kg a.i. per acre, carbofuron 3 G at 0.30 kg a.i. per acre and pyridyl phosphate (dursban) 20 EC at 0.48 kg a. i. per acre were found superior not only to control but over heptachlor 20 EC and 6 per cent dust at 1.81 kg a.i. per acre, chloradane 75 EC at 2.72 kg a.i. per acre, disulphoton (solvirex) 5 G at 0.75 kg a.i. per acre. Under unirrigated conditions none of the chemicals were effective against grass.

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